With 2019 NCEA Exam included

NCEA ANSWERS

Chemistry AS 91164
C2.4 Bonding, Structure and Energy

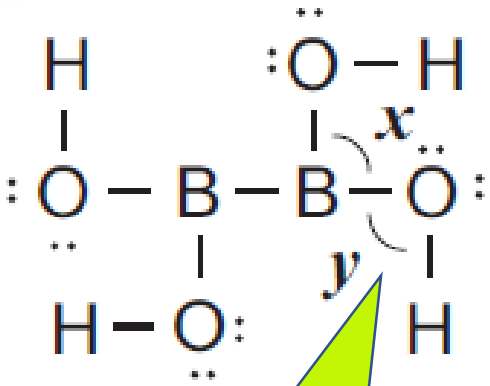
image: Freepik.com

GZ Science Resources

NCEA 2014 Molecule shapes and bond angle

Achieved Question

Question 1b (i) : The Lewis structure for a molecule containing atoms of boron, oxygen, and hydrogen, is shown below.
The following table describes the **shapes around two of the atoms** in the molecule above.
Complete the table with the approximate bond angles *x* and *y*.



Central atom	Shape formed by bonds around the central atom	Approximate bond angle
B	trigonal planar	$x =$ 120°
O	bent	$y =$ 109.5°

Bond angles

2 regions = 180°

3 regions = 120°

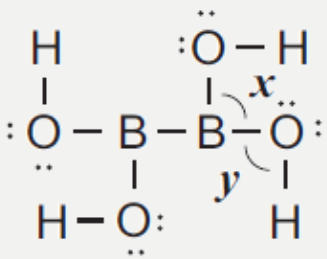
4 regions = 109.5°

Even though this is an unknown molecule focus on each atom and the number of regions of charge around each

NCEA 2014 Molecule shapes and bond angle

Excellence Question

Question 1b (ii): The bond angles *x* and *y* in the molecule above are different. Elaborate on why the bond angles are different.
In your answer you should include:
- factors which determine the shape around the:
- B atom for bond angle *x*
- O atom for bond angle *y*
- reference to the arrangement of electrons around the B and O atoms.



Answer 1b (ii): The B atom has **three regions of electron density** around it. These are all bonding regions. The regions of electron density are arranged to minimise repulsion / are arranged as **far apart as possible** from each other in a **trigonal planar** arrangement. This is why the bond angle is 120°

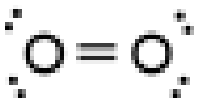
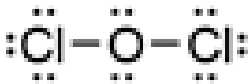
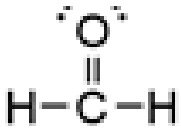
The O atom has **four regions of electron density** around it. The regions of electron density are arranged to minimise repulsion / are arranged **as far apart** as possible from each other in a **tetrahedral** arrangement / two of these are bonding (and two are non-bonding). This is why the bond angle is 109.5°.

NCEA 2015 Lewis Structures

Achieved Question

Q 1a: Draw the Lewis Structure for each of the following molecules

Draw the Lewis structure (electron dot diagram) for each of the following molecules.

Molecule	O_2	OCl_2	CH_2O
Lewis structure			

Look further through the exam paper for hints on drawing

In the past the Lewis structure is a "stand alone" question – which case there is an Achieved point given for the majority correct.

In past years the following molecules have been used:

HCN CH_2Br_2 AsH_3 CH_4 H_2O N_2 PCl_3 CO_2 H_2S

These have one central atom (except N_2) and 2 or more outside attached atoms

NCEA 2015 Molecule shapes and bond angle

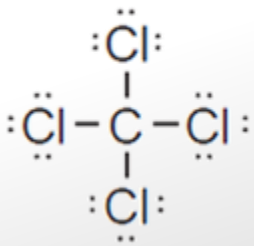
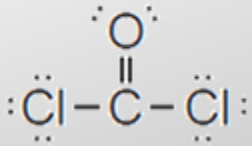
Achieved Question

Question 1b: Carbon atoms can bond with different atoms to form many different compounds. The following table shows the Lewis structure for two molecules containing carbon as the central atom, CCl_4 and $COCl_2$. These molecules have different bond angles and shapes.
Evaluate the Lewis structure of each molecule to determine why they have different bond angles and shapes.
In your answer you should include:

- The approximate bond angle in each molecule
- The shape of each molecule
- Factors that determine the shape and bond angle for each molecule.

Lewis structures are given in the shape and bond angle questions

Make sure you clearly state the correct shape and bond angle **beside each Lewis structure** - before starting the discussion. Use the formula as the "name" for each molecule – you do not have to know the name unless it is given.

Molecule	CCl_4	$COCl_2$
Lewis structure		

NCEA 2015 Molecule shapes and bond angle

Excellence Question

Answer 1b: In each CCl_4 molecule, there are four negative electron clouds / regions around the central C atom. These repel each other as far away from each other as possible in a tetrahedral (base) arrangement, resulting in a 109.5° bond angle. All of these regions of electrons are bonding, without any non-bonding regions, so the shape of the molecule is tetrahedral.

In each $COCl_2$ molecule, there are three negative electron clouds / regions around the central C atom. These repel as far away from each other as possible in a triangular / trigonal planar (base) shape, resulting in a 120° bond angle. All of these regions of electrons are bonding, without any non-bonding regions, so the shape of the molecule is trigonal planar.

Bond angles

2 regions = 180°

3 regions = 120°

4 regions = 109.5°

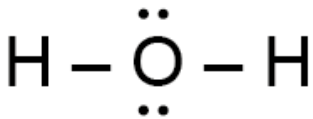
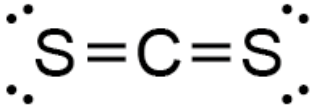
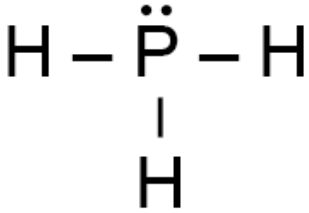
Discuss each molecule separately using the same steps

- ❑ State number of electron regions around central atom
- ❑ State base shape they repel to and the angle
- ❑ State number of bonding/non-bonding regions
- ❑ State final shape (will be the same as base shape if no lone pairs)

NCEA 2016 Molecule shapes and bond angle (part ONE)

Achieved Question

Question 3a (i) : Draw the Lewis structure (electron dot diagram) for each of the following molecules, and name their shapes.

Molecule	H_2O	CS_2	PH_3
Lewis structure			
Name of shape	bent	linear	Trigonal pyramid
Approximate bond angle around the central atom	109.5°	180°	109.5°

NCEA 2016 Molecule shapes and bond angle (part TWO)

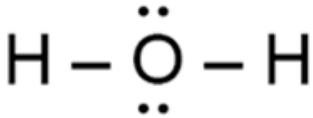
Excellence Question

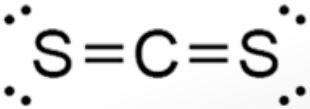
Question 3a (ii): Compare and contrast the shapes and bond angles of H_2O, CS_2 and PH_3.

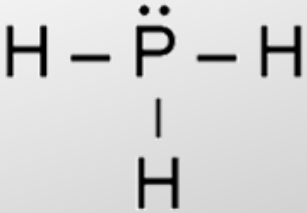
Answer 3a (ii): Bond angle is determined by the number of electron clouds / areas of negative charge around the central atom, which are arranged to minimise repulsion / are arranged as far apart from each other as possible (maximum separation).

Both H_2O and PH_3 have 4 electron clouds / areas of negative charge around the central atom, so the bond angle is that of a tetrahedral arrangement of 109.5**°**, whereas there are only 2 electron clouds / areas of negative charge around the central atom in CS_2, which means minimum repulsion is at 180**°**, resulting in CS_2's shape being linear.

The shapes of H_2O and PH_3 differ despite having the same tetrahedral arrangement because water has two non-bonding pairs of electrons around the central atom, while phosphine only has one non-bonding pair. The resulting shapes are bent or v-shaped for H_2O, while PH_3 is trigonal pyramid



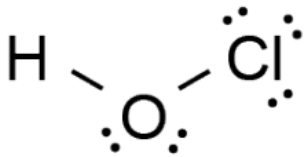
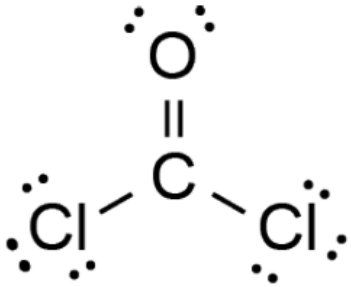
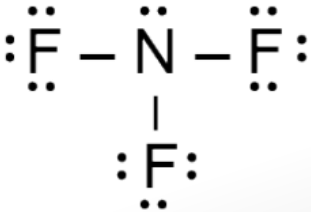




NCEA 2017 Molecule shapes and bond angle (part ONE)

Achieved Question

Question 2a (i) : Draw the Lewis structure (electron dot diagram) for each of the following molecules, and name their shapes.

Molecule	HOCl	$COCl_2$	NF_3
Lewis structure			
Name of shape	bent / v-shaped	trigonal planar	trigonal pyramid
Approximate bond angle around the central atom	109.5°	120°	109.5°

NCEA 2017 Molecule shapes and bond angle (part TWO)

Excellence Question

Question 2a (ii): Justify the shapes and bond angles of HOCl and $COCl_2$.

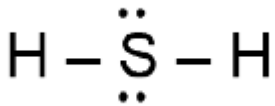
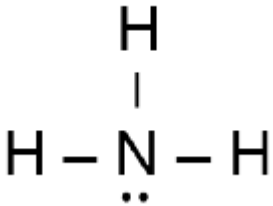
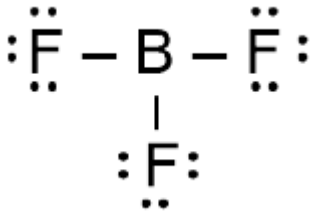
Answer 2a (ii): Bond angle is determined by the **number of electron density regions** around the central atom, which are arranged into a position to minimise repulsion / are **arranged as far apart from each other as possible** (maximum separation).
HOCl has 4 electron density regions / areas of negative charge around the central O atom.
This means the electron density regions around the central atom is arranged with maximum separation in a **tetrahedral shape** with a bond angle of 109.5**°**, to minimise (electron-electron) repulsion. Due to the presence of two non-bonding pairs of electrons / regions (or two bonding regions) on the central O atom, HOCl has an actual shape that is **bent** / v-shaped / angular.

$COCl_2$ has only 3 electron density regions / areas of negative charge around its central C atom so the electron density regions around the central atom is arranged with maximum separation in a **trigonal planar shape** with a bond angle of 120°, to minimise (electron-electron) repulsion. Since $COCl_2$ has only bonding electron pairs (no non-bonding pairs) on its central atom, the actual shape is **trigonal planar** (with bond angles of 120°).

NCEA 2018 Molecule Shape and Bond Angle (part 1)

Achieved Question

Question 2a. Draw the Lewis structure (electron dot diagram) for each of the following molecules, and name their shapes.

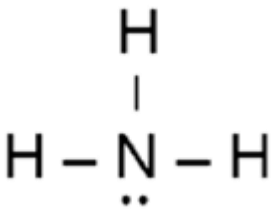
Molecule	H_2S	NH_3	BF_3
Lewis Structure			
Name of Shape	Bent	Trigonal Pyramid	Trigonal Planar
Approximate bond angle around central atom	109.5°	109.5°	120°

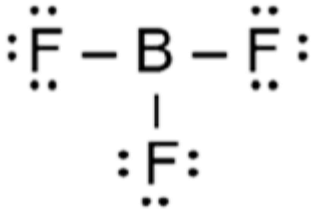
NCEA 2018 Molecule Shape and Bond Angle (part 2)

Excellence Question

Question 2b. Compare and contrast the shapes and bond angles of NH_3 and BF_3.

NH_3 has **four electron clouds / regions of negative charge** around its central N atom. As the electron clouds maximise separation to minimise repulsion they take a **tetrahedral geometry** with a **bond angle of 109.5º**. Three of the regions are bonded and one is non-bonded, so the **overall shape is trigonal pyramid.**





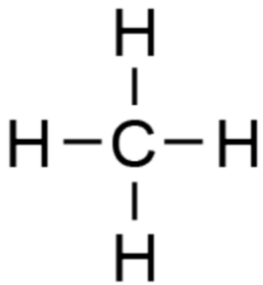
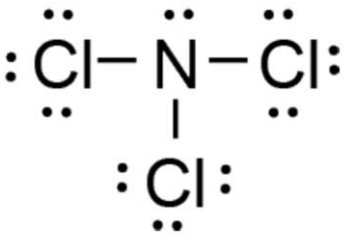
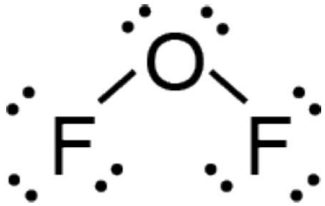
In contrast, BF_3 only has **three regions of negative charge** around its central B atom. As the electron clouds maximise separation to minimise repulsion they take a **trigonal planar geometry** with the bond angle of 120º. While BF_3 has three bonded regions like NH_3, because there is no non-bonding regions BF_3's **shape is trigonal planar.**

So although both molecules have three bonded areas to the central atom, ammonia has a fourth region of negative charge, which is not bonded. This affects its angle and shape.

NCEA 2019 Molecule Shape and Bond Angle (part 1)

Achieved Question

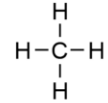
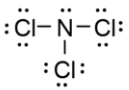
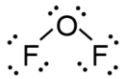
Question 2a. (i) Draw the Lewis structure (electron dot diagram) for the following molecules, and name their shapes.

Molecule	CH_4	NCl_3	OF_2
Lewis structure			
Name of shape	tetrahedral	Trigonal pyramid	bent

NCEA 2019 Molecule Shape and Bond Angle (part 2)

Excellence Question

Question 2a. (ii) The above molecules have different shapes; however each molecule has an approximate bond angle of 109.5°.
Justify this statement by referring to the factors that determine the shape of each molecule.

Molecule	CH_4	NCl_3	OF_2
Lewis structure			
Name of shape	tetrahedral	Trigonal pyramid	bent

Bond angle is determined by the number of electron density regions around the central atom, which are arranged into a position to minimise repulsion by having maximum separation.
All molecules have 4 electron density regions / areas of negative charge around the central atom which arrange with maximum separation into a tetrahedral shape / geometry with a bond angle of (approx.) 109.5° / 109°.
In CH_4 all of the electron pairs are bonded, and so the shape of the molecule is also tetrahedral.
In NCl_3 three of the electron pairs are bonded and one is non-bonding. The observed shape of the molecule is trigonal pyramidal.
In OF_2, due to the presence of two non-bonding pairs of electrons / regions (or two bonding regions) on the central atom, OF_2 has an observed shape that is bent / v-shaped / angular.

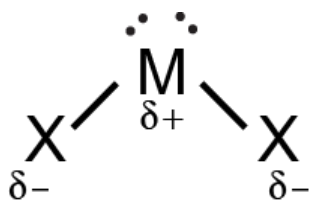
NCEA 2013 Molecule polarity

Excellence Question

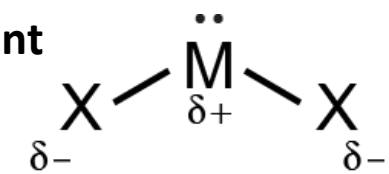
Question 1c (ii): Elements M and X form a compound MX_2. Atoms of element X have a higher electronegativity value than atoms of element M, therefore the M–X bonds are polar. Depending on what elements M and X are, molecules of the compound formed will be **polar** or **non-polar**.
State the most likely shape(s) of the molecule if it is **Polar** and if it is **Non-polar:** Justify your answer and draw diagrams of the possible molecules with dipoles labelled.

If MX_2 is **polar**, this indicates that the polar M–X bonds are not spread symmetrically around the central M atom. There must be either **three or four regions of negative charge** with only two bonded atoms therefore the shape must be bent.

Polar: bent

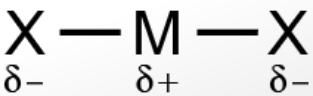


Three regions of negative charge:



Four regions of negative charge:

Non-polar: linear



Two regions of negative charge:

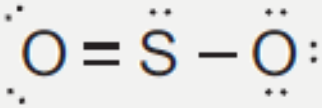
If MX_2 is **non-polar** this means that the polar M-X bonds are spread symmetrically around the central M atom. There must be only **two regions of negative charge** around the M atom, both bonded by X atoms in a linear shape.

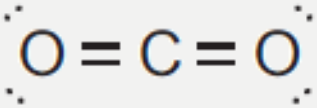
NCEA 2014 Molecule Polarity

Excellence Question

Question 1c: Molecules can be described as being polar or non-polar.
The following diagrams show the Lewis structures for two molecules, **SO_2** and **CO_2**. Identify the polarity

- Justify your choice





When given a multi- choice question **never** leave it blank

State polarity of molecule first
State polarity of bonds (name atoms)
Link symmetry to dipoles cancelling out (or vice versa)

Answer 1c: SO_2 molecule is polar.
CO_2 molecule is non-polar.
The S–O / S=O bond is polar due to the **difference in electronegativity** between S and O atoms. The bonds are arranged **asymmetrically** in a bent shape around the central S atom; therefore the (bond) **dipoles do not cancel** and the molecule is polar.

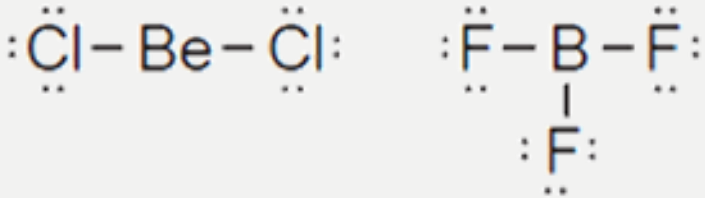
The C=O bond is polar due to the **difference in electronegativity** between C and O atoms. The bonds are arranged **symmetrically** in a linear shape around the central C atom; therefore the (bond) **dipoles cancel** and the molecule is non-polar.

NCEA 2015 Molecule Polarity

Excellence Question

Question 1c: $BeCl_2$ and BF_3 are unusual molecules because there are not enough electrons for the central atoms, Be and N, to have a full valance shell. Their Lewis structures are shown below. Both Molecules have the same polarity.

- Identify the polarity
- Justify your choice



When given a multi- choice question **never** leave it blank

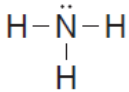
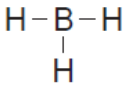
State polarity of molecule first
State polarity of bonds (name atoms)
Link symmetry to dipoles cancelling out (or vice versa)

Answer 1c: Both molecules are non-polar.
The Be-Cl bond is polar because Cl is more electronegative than Be / the atoms have different electronegativities.
Since both the bonds are the same and arranged symmetrically around the central atom, in a linear arrangement, the bond dipoles cancel out, resulting in a non-polar molecule.
The B-F bond is polar because F is more electronegative than B / the atoms have different electronegativities. Since all three bonds are the same and arranged symmetrically around the central atom, in a trigonal planar arrangement, the bond dipoles cancel out, resulting in another non-polar molecule.

NCEA 2016 Molecule Polarity

Excellence Question

Question 3b: The Lewis structures for two molecules are shown.

Molecule	 Ammonia	 Borane
Polarity of molecule	polar	non-polar

Ammonia, NH_3, is polar, and borane, BH_3, is non-polar. Justify this statement.

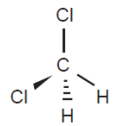
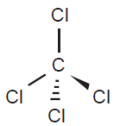
State polarity of molecule first
State polarity of bonds (name atoms)
Link symmetry to dipoles cancelling out (or vice versa)

Answer 3b: Each N-H bond in NH_3 is polar / forms a dipole because the N and H atoms have different **electronegativities.** The shape of the molecule (due to the presence of one non-bonding electron pair) is trigonal pyramidal which is asymmetrical, so the dipoles / bond polarities do not cancel. The **resulting NH_3 molecule is polar.**
Each B-H bond in BH_3 is polar / forms a dipole because the B and H atoms have different **electronegativities.** The shape of the molecule is trigonal planar which is symmetrical, so the dipoles / bond polarities cancel. The **resulting BH_3 molecule is non-polar.**

NCEA 2017 Molecule Polarity

Excellence Question

Question 2b: Three-dimensional diagrams for two molecules are shown below.

Molecule		
Name	Dichloromethane	Tetrachloromethane
Polarity of molecule	polar	Non-polar

(i) In the boxes above, identify the polarity of each molecule, by writing either **polar** or **non-polar.**
(ii) Justify your choices.

State polarity of molecule first
State polarity of bonds (name atoms)
Link symmetry to dipoles cancelling out (or vice versa)

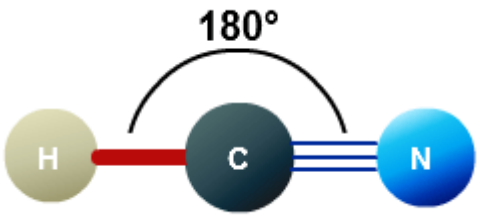
In CCl_4, the four C–Cl bonds are polar, i.e. have a dipole, due to the difference in electronegativity between C and Cl. These (equally sized) dipoles are arranged in a symmetric **tetrahedral** shape, resulting in the dipoles / bond polarities cancelling each other out, so CCl_4 is non-polar.
In CH_2Cl_2, there are two types of bond, C–H and C–Cl, each polar with dipoles due to the difference in electronegativity between C and H and C and Cl. These dipoles have different polarities / sizes as H and Cl have different electronegativities. (Despite the symmetric tetrahedral arrangement) the different (sized) dipoles / bond polarities do not cancel each other out, so CH_2Cl_2 is polar.

NCEA 2018 Molecule Polarity

Excellence Question

Question 2c. The Lewis structures for two molecules are shown below.
Hydrogen cyanide, HCN, is polar, and carbon dioxide, CO_2, is nonpolar.
Both molecules are linear.
Explain why the polarities of the molecules are different, even though their shapes are the same.

Molecule	H−C≡N	O=C=O
Polarity of molecule	Polar	Nonpolar



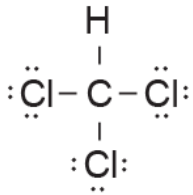
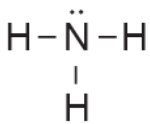
In HCN, the **two bonds are polar** due the **difference in electronegativity** between H and C, and C and N. The resulting bond dipoles are differing in size as H and N have different electronegativities, so despite the symmetric linear arrangement **the bond dipoles do not cancel** and HCN is overall polar.

The **C=O bond is also polar** due to O being more electronegative than C giving these bonds dipoles. But because both **bonds are identical and are arranged symmetrically** in a linear shape, the **bond dipoles cancel** and the molecule is non-polar overall.

NCEA 2019 Molecule Polarity

Excellence Question

Question 2b. The following table shows the Lewis structures (electron dot diagrams) for the molecules, $CHCl_3$ and NH_3.

Molecule	$CHCl_3$	NH_3
Lewis structure		
Polarity	Polar	Polar

(i) In the boxes beside, identify the polarity of each molecule by writing either **polar** or **non-polar**.
(ii) Justify your choices.

In $CHCl_3$, there are two types of bond, C–H and C–Cl, each polar, due to the difference in electronegativity between C and H and C and Cl atoms. These dipoles have different polarities / sizes as H and Cl have different electronegativities. (Despite the tetrahedral arrangement appearing symmetrical) the different (sized) bond dipoles do not cancel each other out, so $CHCl_3$ is polar.
In NH_3, the three N–H bonds are polar, i.e. have a dipole, due to the difference in electronegativity between N and H atoms. These (equally sized) dipoles are arranged in a non-symmetrical trigonal pyramidal shape, resulting in the bond dipoles not cancelling each other out, so NH_3 is polar.

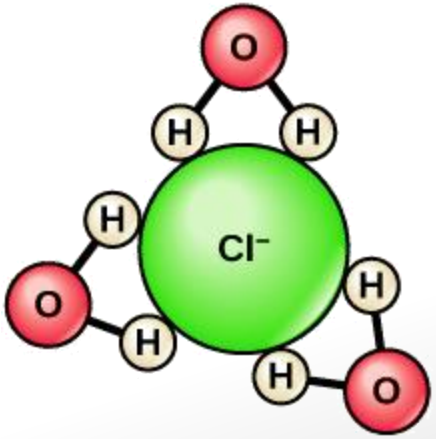
NCEA 2014 Solubility

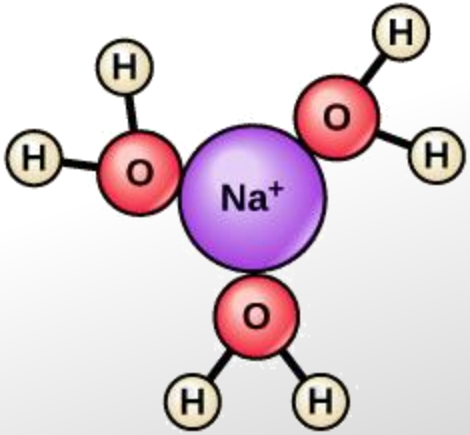
Excellence Question

Question 3b: Use your knowledge of structure and bonding to explain the dissolving process of sodium chloride in water.
Support your answer with an annotated (labelled) diagram.

Answer 3b : Solubility

When sodium chloride is dissolved in water the **attractions** between the polar water molecules and between the ions in the salt are replaced by attractions between the water molecules and the ions. The negative charges on the oxygen ends of the water molecules are attracted to the positive Na^+ ions, and the positive hydrogen ends of the water molecules are attracted to the negative Cl^- ions.





Only a few ions of each are needed in the diagram. Don't forget to label

NCEA 2017 Solubility

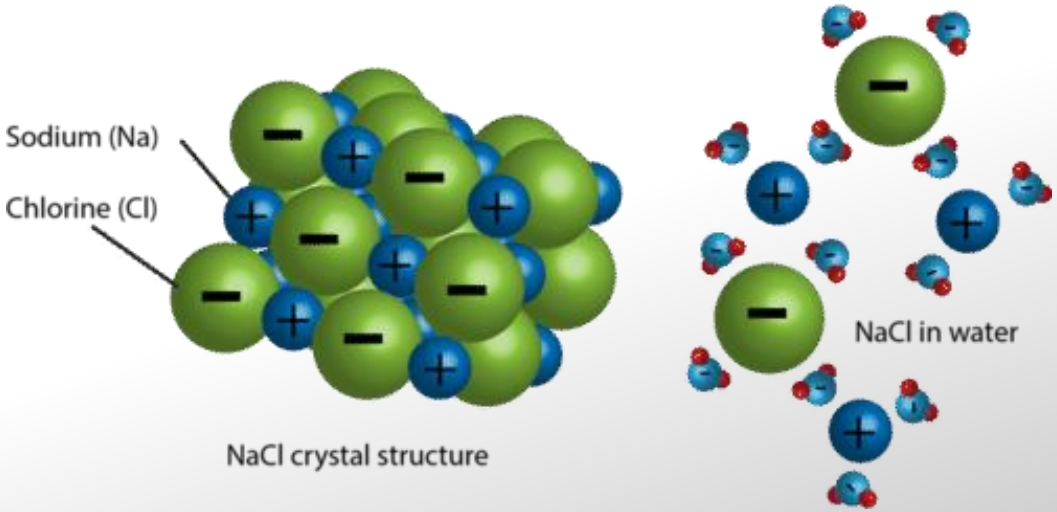
Excellence Question

Question 1b: (iii) Sodium chloride, NaCl, is another compound that is excreted from the body in sweat.
Use your knowledge of structure and bonding to explain the dissolving process of sodium chloride, NaCl, in water.
Support your answer with a labelled diagram.

Only a few ions of each are needed in the diagram. Don't forget to label

Answer 3b : Solubility

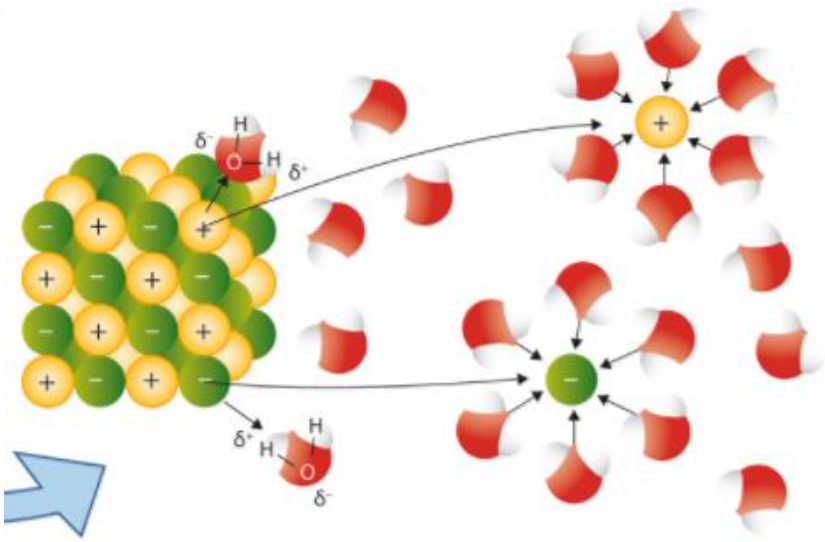
Sodium chloride is an ionic substance made up of Na^+ and Cl^- ions arranged in a (3D) lattice and held together by ionic bonds. The δ- O of polar water molecules are attracted to the positive Na^+, while water's δ+ H is attracted to the negative Cl^-, this attraction is sufficiently strong to overcome the attractions between the ions in the salt / crystal /lattice (and between the water molecules in the solvent), dissolving the NaCl.



NCEA 2018 Solubility

Excellence Question

Question 3d (i) . Use an annotated diagram to show how solid **A (ionic solid)** is able to dissolve in water.
Show the solid before dissolving, and the dissolving process of the solid.
(ii) Explain the attractions that allow solid **A** to be soluble in water.



Solid A is ionic and when it dissolves in water, it **separates into its ions**. The ions are **charged** and are attracted to the charged ends of the polar water molecule. The slightly negative charges on the oxygen ends of the water molecules are attracted to the positive ion, and the slightly positive hydrogen ends of the water molecules are attracted to the negative ions. **This causes the ions to be surrounded by water molecules and it dissolves.**

This solid is soluble because the **force of attraction between the ions and water is strong enough to overcome the forces holding the ions together** along with the forces holding the water molecules together (in the solvent).

NCEA 2019 Solubility

Excellence Question

Question 1c Compare the solubilities of iodine, $I_{2(s)}$, in water, $H_2O_{(l)}$ – a polar solvent, and in cyclohexane, $C_6H_{12(l)}$ – a non-polar solvent.
Use your knowledge of structure and bonding to explain the solubility of iodine in these two solvents.

Iodine is a non-polar (covalent) molecular substance made up of I_2 molecules held
together by weak intermolecular forces.
Iodine is soluble in cyclohexane, but does not easily dissolve in water.
For iodine in water, the iodine-water attractions are not strong enough to overcome both the iodine-iodine / solute-solute and the strong water-water / solvent-solvent attractions.

For iodine in cyclohexane, the iodine-cyclohexane attractions are strong enough to overcome iodine-iodine / solute-solute and cyclohexane-cyclohexane / solvent-solvent attractions because all attractive forces are similar (nonpolar).

NCEA 2013 Solids

Merit Question

Question 2a: Complete the table below by stating the type of substance, the type of particle, and the bonding (attractive forces) between the particles for each of the substances.

Substance (for example)	**Type of substance**	**Type of particle**	**Attractive forces between particles**
$C_{(s)}$ Graphite	Covalent network	Atom	Covalent (and weak intermolecular forces)
$Cl_{2\ (s)}$ chlorine	Molecular	Molecules	Weak intermolecular forces
$CuCl_{2(s)}$ copper chloride	Ionic	Ion	Ionic bonds / electrostatic attraction
$Cu_{(s)}$ copper	Metal	Atom / cations and electrons	Metallic bonds / electrostatic attraction

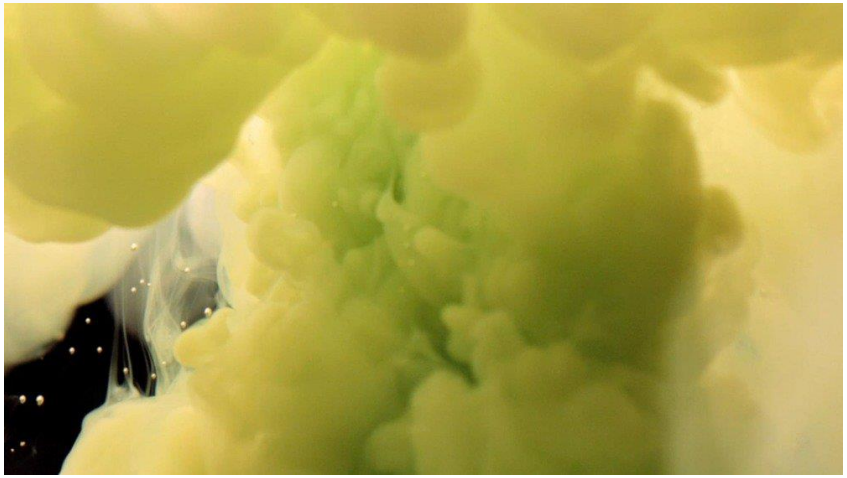
This chart needs to be learnt

There will not necessarily be one example for each group but information from this chart MUST be used in following questions about solids

NCEA 2013 Solids

Merit Question

Question 2b: Explain why chlorine is a gas at room temperature, but copper chloride is a solid at room temperature.
In your answer, you should refer to the particles and the forces between the particles in **both** substances.



Chlorine is a molecular substance composed of chlorine molecules held together by weak intermolecular forces. The weak intermolecular forces do not require much heat energy to break, so the boiling point is low (lower than room temperature); therefore chlorine is a gas at room temperature.

Copper chloride is an ionic substance. It is composed of a lattice of positive copper ions and negative chloride ions held together by electrostatic attraction between these positive and negative ions. These are strong forces, therefore they require considerable energy to disrupt them and melt the copper chloride; hence copper chloride is a solid at room temperature.

NCEA 2013 Solids - (PART ONE)

Excellence Question

Question 2b (ii) : Using your knowledge of structure and bonding, explain why, although both graphite and copper are good conductors of electricity, copper is suitable for electrical wires, but graphite is not.

For a substance to conduct electricity, it must have charged particles which are free to move.

Graphite is a covalent network solid composed of layers of C atoms covalently bonded to three other C atoms. The remaining valence electron is delocalised (ie free to move) between layers; therefore these delocalised electrons are **able to conduct** electricity.

Copper is a metallic substance composed of copper atoms packed together. Valence electrons are loosely held and are attracted to the nuclei of the neighbouring Cu atoms; ie the bonding is non-directional. These delocalised valence electrons are **able to conduct** an electrical current.

NCEA 2013 Solids - (PART ONE)

Excellence Question

Question 2b (ii) : Using your knowledge of structure and bonding, explain why, although both graphite and copper are good conductors of electricity, copper is suitable for electrical wires, but graphite is not.

For a substance to be made into wires, it needs to be stretched or drawn out without breaking.

In **graphite**, the attractive forces holding the layers together are very weak and are broken easily, so the layers easily slide over one another, but the attraction is not strong enough to hold the layers together and allow it to be drawn into wires or although the layers can slide due to weak forces, if graphite was to be made into a wire the very strong covalent bonds within the layers would have to be broken

Copper metal is malleable and can easily be drawn into wires since, as it is stretched out, the non-directional metallic bonding holds the layers together, allowing it to be stretched without breaking.

NCEA 2014 Solids

Achieved Question

Question 2a: Complete the table below by stating the type of substance, the type of particle, and the type of bonding (attractive forces) between the particles for each of the two substances. Mg (magnesium) and I_2 (iodine)

This chart needs to be learnt

Answer 2a:

	Type of substance	Type of particle	Attractive forces between particles
Mg	Metallic	Atoms / cations and electrons	Metallic bonds / electrostatic attraction between positive ion (cation) and electron
I_2	Molecular	Molecules	Intermolecular forces

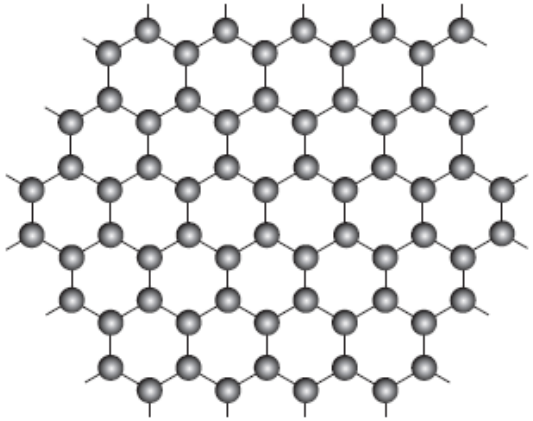
There will not necessarily be one example for each group but information from this chart MUST be used in following questions about solids

Identify Metal first then Ionic (metal + non-metal), next Covalent network (C or SiO_2) and then molecular (non-metal + non-metal)

NCEA 2014 Solids

Excellence Question

Question 2b: Graphene is a new 2-dimensional material made of carbon atoms. Graphene can be described as a 'one-atom-thick' layer of graphite. A diagram of graphene and two of its properties is shown below. Use your knowledge of structure and bonding to explain the two properties of graphene given above.



Properties of graphene:

Melting point: very high

Electrical conductivity: excellent

Answer 2b: Graphene has strong covalent bonds. Because the covalent bonds are strong / there are a large number of covalent bonds, it requires a lot of energy to break these bonds, and therefore the melting point is high.

Each carbon atom is bonded to only three other carbon atoms. Therefore each carbon atom has free / delocalised /valence electron(s), to conduct electricity.

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NCEA 2014 Solids - (Part ONE)

Excellence Question

Question 2c: Solid Mg and I_2 were tested for three physical properties. The table below shows the results of the tests. Use your knowledge of structure and bonding to explain the results of the tests.

Refer back to particle chart

	Physical property		
Substance tested	Ductile	Soluble in cyclohexane (non-polar solvent)	Conducts electricity
Mg	yes	no	yes
I_2	no	yes	no

Answer 2c: Magnesium atoms are held together in a 3–D lattice by metallic bonding in which valence electrons are attracted to the nuclei of neighbouring atoms.
Iodine molecules are held together by weak intermolecular forces.

REMEMBER: (Properties are limited to hardness (including malleability and ductility), electrical conductivity, melting and boiling points and solubility)

NCEA 2014 Solids - (Part TWO)

Excellence Question

Question 2c: Solid Mg and I_2 were tested for three physical properties. The table below shows the results of the tests. Use your knowledge of structure and bonding to explain the results of the tests.

Refer back to particle chart

	Physical property		
Substance tested	Ductile	Soluble in cyclohexane (non-polar solvent)	Conducts electricity
Mg	yes	no	yes
I_2	no	yes	no

Answer 2c: Ductility

The attraction of the Mg atoms for the valence electrons is not in any particular direction **(non-directional)** ; therefore Mg atoms can move past one another without disrupting the metallic bonding, therefore Mg is **ductile**.

The attractions between iodine molecules are **directional**. If pressure is applied the repulsion between like-charged ions will break the solid (brittle) , therefore I_2 is **not ductile**.

NCEA 2014 Solids - (Part THREE)

Excellence Question

	Physical property		
Substance tested	Ductile	Soluble in cyclohexane (non-polar solvent)	Conducts electricity
Mg	yes	no	yes
I_2	no	yes	no

Refer back to particle chart

Answer 2c: Dissolving in cyclohexane

Magnesium **does not dissolve in cyclohexane** because cyclohexane molecules are not attracted to the magnesium atoms in the metallic lattice.

Iodine **is soluble**, as iodine is a non-polar molecule. The iodine molecules and cyclohexane molecules form weak intermolecular attractions.

Electrical conductivity

Valence electrons of Mg atoms are free to move throughout the structure. This means that magnesium can conduct electricity. There are free moving charge particles.

Iodine does not conduct electricity as it does not contain delocalised electrons (free moving charged particles). Molecules are neutral compounds.

NCEA 2015 Solids

Merit Question

Question 3a: Complete the table below by stating the type of solid, the type of particle, and the attractive forces between the particles in each solid.

This chart needs to be learnt

Answer 3a:

Substance	Type of Substance	Type of particle	Attractive forces between particles
Cu(*s*)	metal / metallic	Atom (or cation and delocalised electrons)	metallic bond
PCl_3(*s*)	molecular	molecule	intermolecular (forces)
SiO_2(*s*)	covalent network	atom	covalent bond
KCl(*s*)	ionic	ion	ionic bond

There will not necessarily be one example for each group but information from this chart MUST be used in following questions about solids

Identify Metal first then Ionic (metal + non-metal), next Covalent network (C or SiO_2) and then molecular (non-metal + non-metal)

NCEA 2015 Solids

Excellence Question

Question 3b: Phosphorus trichloride, PCl_3, is a liquid at room temperature, and does not conduct electricity.
Explain these two observations in terms of the particles, structure, and bonding of PCl_3.

Refer back to particle chart

Answer 3b: Phosphorus trichloride, PCl_3, is a **molecular solid**, made up of non-metal phosphorus and chlorine atoms **covalently** bonded together. The molecules are held together by **weak intermolecular forces**. Since these forces are weak, not much energy is required to overcome them, resulting in low melting / boiling points. (In the case of PCl_3, its melting point is lower than, and its boiling point is higher than room temperature, so it is liquid.)

PCl_3 does not contain free moving ions nor any delocalised / free moving valence electrons, meaning PCl_3 **does not contain any charged particles**. Since free moving charged particles are required to carry electrical current, PCl_3 is unable to conduct electricity.

REMEMBER: (Properties are limited to hardness (including malleability and ductility), electrical conductivity, melting and boiling points and solubility)

NCEA 2015 Solids - (Part ONE)

Excellence Question

Question 3c: Consider each of the solids copper, Cu, silicon dioxide, SiO_2, and potassium chloride, KCl.
Complete the table below by identifying which of these solids have the listed physical properties:

Refer back to particle chart

Physical properties	Solid
The solid is insoluble in water and is malleable.	METAL - copper
The solid is soluble in water and is not malleable.	IONIC – potassium chloride
The solid is insoluble in water and is not malleable.	COVALENT NETWORK – silicon dioxide

REMEMBER: Draw up a quick chart for each physical property and each solid

NCEA 2015 Solids - (Part TWO)

Excellence Question

Answer 3c: Justify TWO of your choices in terms of the particles, structure, and bonding of these solids. You may use diagrams in your justification.

Refer back to particle chart

State the properties and solid type

Cu is **insoluble in water and malleable**.

1. Copper is a metal made up of an array of atoms (or ions) held together by **non-directional forces** between the positive nuclei of the atoms and the delocalised / free moving valence electrons.
2. There is no attraction between the copper atoms and the (polar) water molecules, therefore Cu is **insoluble in water**.
3. Since the attractive forces are non-directional, when pressure is applied, the Cu atoms can move past each other to change shape without the bonds breaking, so Cu **is malleable**. (Note – labelled diagrams can provide replacement evidence).

REMEMBER: discuss solid structure first then each of the properties. You need both properties for full marks.

NCEA 2015 Solids - (Part TWO)

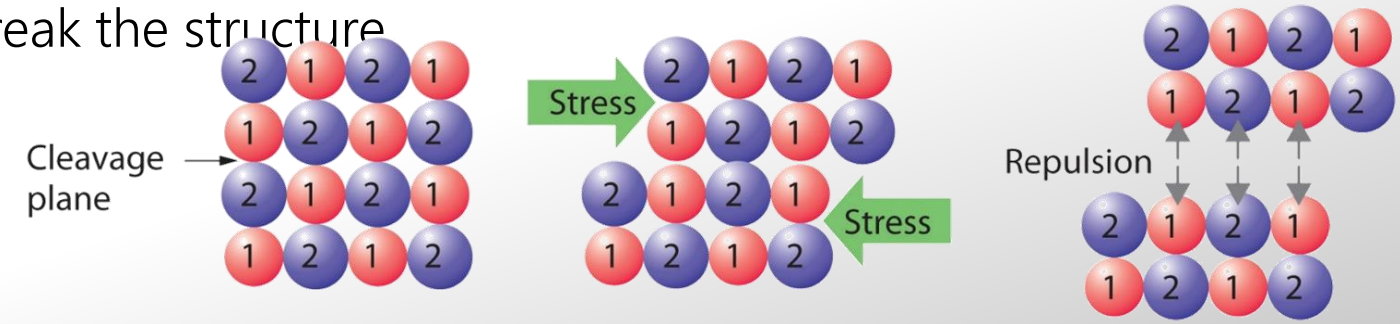
Excellence Question

Question 3c: Justify TWO of your choices in terms of the particles, structure, and bonding of these solids. You may use diagrams in your justification.

Refer back to particle chart

KCl is **soluble in water and not malleable**.

1. KCl is made up of positive K^+ ions, and negative Cl^- ions, ionically bonded in a 3D lattice.
2. When added to water, polar water molecules form electrostatic attractions with the K^+ and Cl^- ions. The partial negative charge, δ^-, on oxygen atoms in water are attracted to the K^+ ions and the partial positive, δ^+, charges on the H's in water are attracted to the Cl^- ions, causing KCl to **dissolve in water**.
3. KCl is **not malleable** because if pressure is applied to an ionic lattice, it forces ions with the same charge next to each other; they repel each other and break the structure.



NCEA 2015 Solids - (Part TWO)

Excellence Question

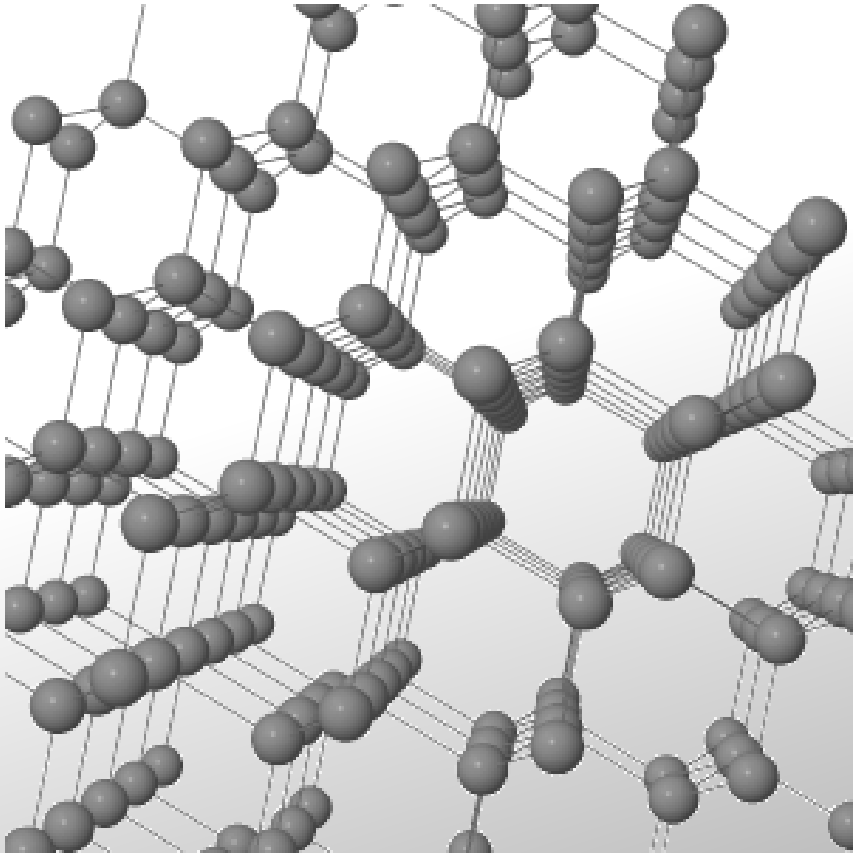
Question 3c: Justify TWO of your choices in terms of the particles, structure, and bonding of these solids. You may use diagrams in your justification.

Refer back to particle chart

SiO_2 is insoluble in water and not malleable.

1. SiO_2 is a **covalent network** made up of atoms covalently bonded together in a 3D lattice structure.
2. (Covalent bonds are strong), Polar water molecules are not strong / insufficiently attracted to the Si and O atoms, therefore **SiO_2 is insoluble** in water.
3. SiO_2 is not malleable because if pressure is applied, the directional / strong covalent bonds have to be broken before the atoms can move.

(Note - labelled diagrams can provide replacement evidence).



NCEA 2016 Solids

Achieved Question

Question 2a: Complete the table below by stating the type of substance, the type of particle, and the attractive forces between the particles in the solid for each substance.

This chart needs to be memorised

Answer 2a:

Substance	Type of substance	Type of particle	Attractive forces between particles
$ZnCl_2(s)$ (zinc chloride)	ionic	ions	ionic
C(s) (graphite)	covalent network	atoms	covalent
$CO_2(s)$ (carbon dioxide / dry ice)	molecular	molecules	intermolecular

There will not necessarily be one example for each group but information from this chart MUST be used in following questions about solids

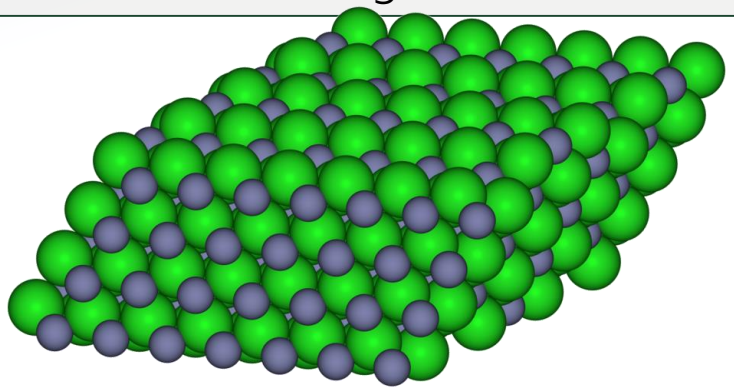
Identify Metal first then Ionic (metal + non-metal), next Covalent network (C or SiO_2) and then molecular (non-metal + non-metal)

NCEA 2016 Solids - (PART ONE)

Excellence Question

Question 2b : Carbon (graphite) conducts electricity when it is solid, whereas zinc chloride, $ZnCl_2$, will not conduct electricity when solid, but will conduct when molten.
Justify this statement in terms of the particles, structure, and bonding for both substances.

For a substance to conduct electricity, it must have charged particles which are free to move.



Graphite is a covalent network solid composed of layers of C atoms covalently bonded to three other C atoms. The remaining valence electron is delocalised (ie free to move) between layers; therefore these delocalised electrons are **able to conduct** electricity.

$ZnCl_2$ is an ionic compound that cannot conduct electricity when solid because the ions (charged particles) are fixed in place in a 3D lattice structure and unable to move. When molten, the ionic bonds between the ions break, so the ions are free to move in the molten liquid. With charged particles / ions free to move, $ZnCl_2$ can then conduct electricity.

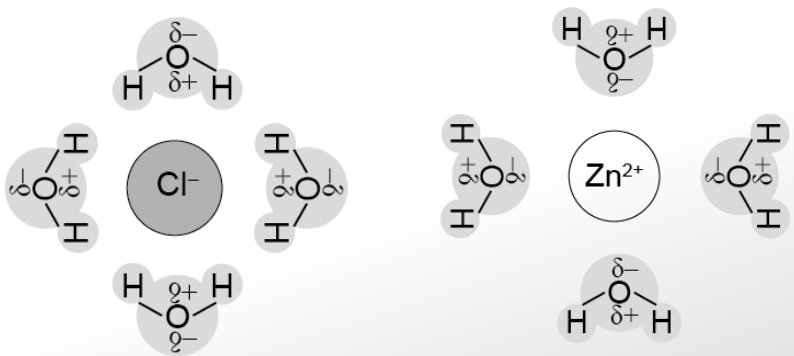
NCEA 2016 Solids - (PART TWO)

Excellence Question

Question 2c : Solid zinc chloride, $ZnCl_{2(s)}$, is soluble in water. Dry ice, $CO_{2(s)}$, is not readily soluble in water. Justify these statements in terms of the particles, structure, and bonding of these substances.

For a substance to be soluble Polar water molecules need to be insufficiently attracted to the particles of the substance placed in

Polar water molecules attract the ions in **zinc chloride's** 3-D lattice strongly enough to separate and dissolve them. The negative charges on the oxygen ends of the water molecules are attracted to the positive Zn^{2+} ions, and the positive hydrogen ends of the water molecules are attracted to the negative Cl^- ions, forming hydrated ions that can spread out through the solution. Therefore it is soluble.



The polar water molecules are unable to interact with the non-polar **carbon dioxide** molecules strongly enough to break the intermolecular forces between the carbon dioxide molecules. Therefore it is not soluble.

NCEA 2017 Solids - (PART ONE)

Merit Question

Question 3a : Complete the table below by stating the type of solid, the type of particle, and the type of bonding (attractive forces) between the particles in each solid.

Solid	Type of solid	Type of particle	Attractive forces between particles
$Al(s)$ (Aluminium)	*metal / metallic*	*atoms (or cations and delocalised valence electrons)*	*metallic (bonds)*
$MgCl_2(s)$ (Magnesium chloride)	*ionic compound*	*ions*	*ionic (bonds)*
$S_8(s)$ (Sulfur)	*molecular*	*molecules*	*intermolecular (bonds)*

NCEA 2017 Solids - (PART TWO)

Excellence Question

Question 3b: Circle the substance which has the lowest melting point.

$Al_{(s)}$ $MgCl_{2(s)}$ $S_{8(s)}$

Justify your choice, referring to the attractive forces between the particles of ALL three substances.

Sulfur has the lowest melting point.
Sulfur is a molecular substance with weak intermolecular forces between the molecules.
These forces do not require much energy to overcome, so they will break at lower temperatures, giving sulfur a lower melting point.
Al is a metal with strong metallic bonds. These attractions require a lot of energy to overcome, so the melting point is higher than sulfur's melting point.
$MgCl_2$ is an ionic compound with strong ionic bonds between the cations and anions.
These bonds also require a lot of energy to overcome, so the melting point is also higher than sulfur's melting point.

NCEA 2017 Solids - (PART THREE)

Excellence Question

Question 3c: Circle the substance which is malleable.

$Al_{(s)}$ $MgCl_{2(s)}$ $S_{8(s)}$

Justify your choice by referring to the structure and bonding of your chosen substance.

You may include a diagram or diagrams in your answer.

Aluminium is malleable.

Aluminium is a metal made up of atoms / cations in a sea of electrons which are held together by non-directional metallic bonds in a (3D) lattice. The metallic bonds are non-directional as the (bonding) electrons are delocalised across the lattice / shared by many atoms. When a force (or pressure) is applied the atoms / layers can move without breaking / disrupting these non-directional bonds thus the structure can change shape without breaking the lattice.

NCEA 2018 Solids

Achieved Question

Question 3a. Complete the table below by choosing the appropriate type of solid that matches the properties shown in the table.
Types of solid: **Ionic**, **Metallic**, **Covalent Network**, **Molecular**.

Solid	Melting point (°C)	Boiling point (°C)	Conducts electricity?	Soluble in water?	Type of solid
A	290	732	solid – no molten – yes	Yes, solution conducts electricity	Ionic
B	44	280	No	No	Molecular
C	1710	2230	No	No	Covalent Network
D	660	2470	Solid and molten – yes	No	Metallic

NCEA 2018 Solids

Excellence Question

Question 3b. Explain why Solid **A** does not conduct electricity in the solid state, but will conduct when molten or when dissolved in water.
Refer to the particles, structure, and bonding of this substance.

Electrical conductivity requires a substance to have **mobile (free moving) charged particles**.
Solid A is an ionic solid made up of a 3-D lattice of positive and negative ions (cations and anions) that are attracted to each other.

- In the **solid** state, these ions are **rigidly held in a lattice by strong ionic bonds**, so cannot move around.
- When **molten**, the ions are able to move freely so it can conduct electricity.
- In **aqueous solution**, the ions are also free to move so the solution can also conduct electricity.

Solid	Melting point (°C)	Boiling point (°C)	Conducts electricity?	Soluble in water?	Type of solid
A	290	732	solid – no molten – yes	Yes, solution conducts electricity	Ionic

https://www.learnis.ru/476728/

NCEA 2018 Solids

Excellence Question

Question 3c. Elaborate on the differences in the melting points of solids **B** and **D** with reference to their particles, structure, and bonding.

Solid B is composed of discrete covalent molecules which are held together by weak intermolecular forces. These weak intermolecular forces are easily broken, so the molecules can be separated with little energy, therefore the melting point is low.

Solid D is a metal made of a 3-D lattice of metal atoms surrounded by a sea of delocalised valence electrons, which are strongly attracted to all the nuclei in the lattice. This forms a strong metallic bond which requires a large amount of energy to break, therefore the melting point is high at 660°C.

Solid	Melting point (°C)	Boiling point (°C)	Conducts electricity?	Soluble in water?	Type of solid
A	290	732	solid – no molten – yes	Yes, solution conducts electricity	Ionic
B	44	280	No	No	Molecular
C	1710	2230	No	No	Covalent Network
D	660	2470	Solid and molten – yes	No	Metallic

https://www.livescience.com/18247-metals-human-body-health-nigms.html

NCEA 2019 Solids

Achieved Question

Question 1a. Complete the table below by stating the type of solid, the type of particle, and the type of bonding (attractive forces) between the particles in each solid.

Solid	Type of solid	Type of particle	Attractive forces between particles
Na(*s*) (sodium)	Metal / metallic	Atoms/cations in a sea of delocalised electrons	Metallic bond
NaI(*s*) (sodium iodide)	ionic	ions	Ionic bond / electrostatic attraction between (oppositely charged) ions
I_2(*s*) (iodine)	(covalent) molecular	molecules	(weak) intermolecular (forces)

NCEA 2019 Solids

Excellence Question

Question 1b. Sodium, Na(*s*), is malleable, whereas sodium iodide, NaI(*s*), is brittle. Explain these observations by referring to the structure and bonding of each substance.

Sodium is a metallic solid made up of atoms in 3D lattice held together by nondirectional metallic bonds (or cations non-directionally electrostatically attracted to a surrounding sea of electrons). When a force (or pressure) is applied, the atoms / layers can move without breaking / disrupting these non-directional bonds; thus the structure can change shape.

NaI is made up of alternating positive ions / Na^+ ions, and negative ions / I^- ions, ionically bonded in a 3D lattice. NaI is not malleable because if pressure is applied to an ionic lattice, it forces ions with the same charge next to each other; they repel each other and break the structure.

NCEA 2019 Solids

Excellence Question

Question 3a. Classify the following chemical process as exothermic or endothermic and give a reason for your choice.

(i) $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta_r H = -394$ kJ mol^{-1}

(ii) In the reaction above, $C_{(s)}$ in the form of graphite can conduct electricity. The product, carbon dioxide, $CO_{2(g)}$, does not conduct electricity.

Use your knowledge of structure and bonding to explain this observation.

Exothermic as $\Delta_r H$ is negative.

To be able to conduct electricity, there needs to be mobile/free moving charged particles. Graphite, $C_{(s)}$, is an extended covalent network solid. Each carbon atom is covalently bonded to 3 other carbon atoms in hexagonal layers. This leaves one delocalised electron per carbon atom that is mobile and able to carry a charge, so graphite conducts electricity.

Carbon dioxide is a covalent molecule. The molecules are held together by weak intermolecular forces, so it is a gas at room temperature. There are no free moving ions or electrons in their structure. Therefore, it can't conduct electricity.

NCEA 2013 Enthalpy

Merit Question

Question 3a: Dissolving ammonium nitrate in a beaker containing water can be represented by the following equation:

$NH_4NO_{3(s)} \rightarrow NH_4^+{}_{(aq)} + NO_3^-{}_{(aq)}$ $\Delta_r H° = 25.1$ kJ mol^{-1}

Give the term below that best describes this process and give the description that best describes what you would observe happening to the beaker during this process.

Answer 3a: Endothermic - Gets colder

The process is endothermic since the enthalpy change (ΔrH°) is positive, which indicates that energy is absorbed by the system as the ammonium nitrate dissolves. Since heat energy is absorbed by the system from the surroundings (water & beaker), the water or beaker will get cooler as they lose heat energy.

Heat absorbed is always endothermic

Question 3b: Glucose is an important source of energy in our diet. The equation below shows the combustion of glucose to form carbon dioxide and water.

$C_6H_{12}O_{6(s)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(\ell)}$ $\Delta_r H° = -2\,820$ kJ mol^{-1}

Give the term below that best describes this process and give a reason

Answer 3b: Exothermic

The reaction is exothermic because the enthalpy change (ΔrH°) is negative; indicating that heat energy is produced during the reaction.

NCEA 2014 Enthalpy

Achieved Question

Question 3a (i): When solid sodium hydroxide is added to water, the temperature increases.

- Identify the term that best describes this reaction
- Give a reason for your choice

Answer 3a (i) : Exothermic, as the temperature increases, which shows energy is being released.

Heat released is always exothermic

Question 3a(ii): The freezing of water to form ice can be represented by the following equation.

$H_2O_{(l)} \rightarrow H_2O_{(s)}$

- Identify the term that best describes this reaction
- Give a reason for your choice

Answer 3a(ii): Exothermic, weak intermolecular attractions form between the water molecules, this releases energy.

NCEA 2015 Enthalpy

Achieved Question

Question 2a: Hand warmers contain a supersaturated solution of sodium ethanoate which, when activated, crystallises and releases heat.

- Identify the term that best describes this reaction
- Give a reason for your choice

Answer 2a: Exothermic because the temperature of the solution increases / heat is released / particles slow down / bonds are formed

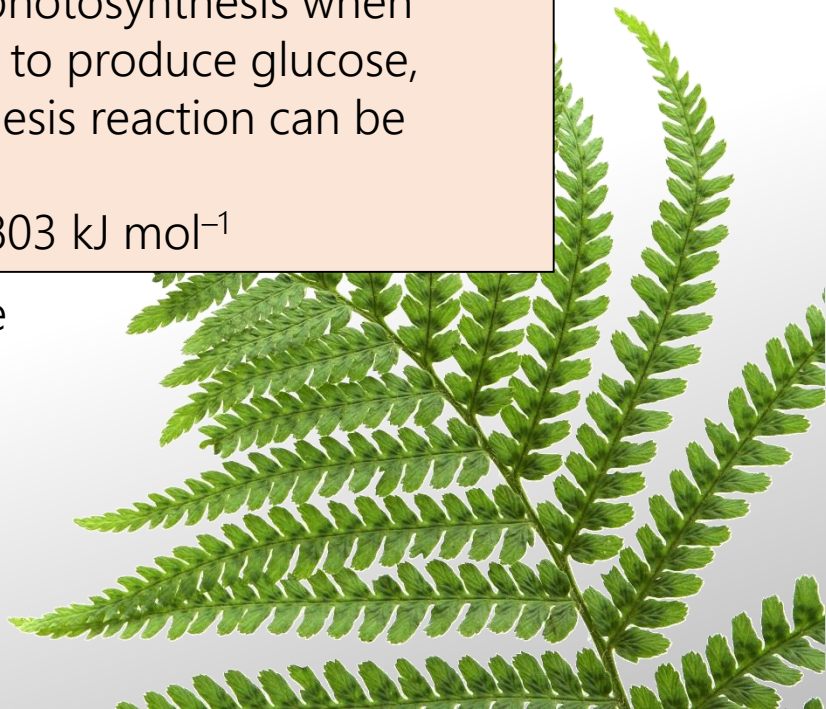
Heat released is always exothermic

Question 2b(i): Glucose is made in plants during photosynthesis when carbon dioxide gas, $CO_{2(g)}$, and water, $H_2O_{(l)}$, react to produce glucose, $C_6H_{12}O_{6(aq)}$, and oxygen gas, $O_{2(g)}$. The photosynthesis reaction can be represented by the following equation:

$6CO_{2(g)} + 6H_2O_{(l)} \rightarrow C_6H_{12}O_{6(aq)} + 6O_{2(g)}$ $\Delta_r H° = +2803$ kJ mol^{-1}

Answer 2b(i): Endothermic because the $\Delta_r H°$ value is positive / it uses the sun's energy

Always attempt these questions as there is only 2 possible answers



NCEA 2015 Enthalpy

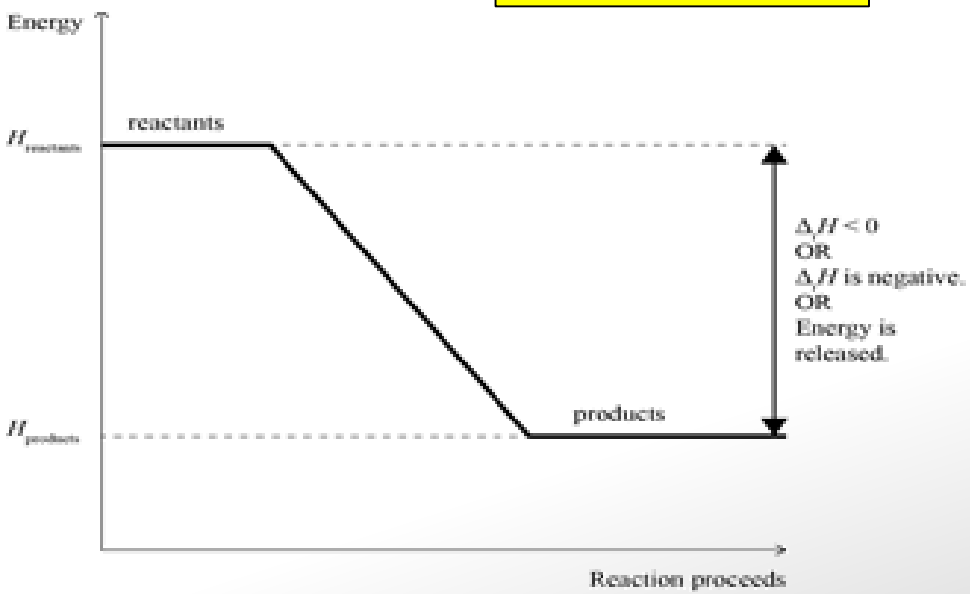
Excellence Question

Question 2c (iii): Complete, including labels, the energy diagram for the combustion of butane gas showing reactants, products, and the change in enthalpy.

Question 2c (iv): Butane gas is a useful fuel because when it undergoes combustion, energy is released. Explain why energy is released in this reaction, in terms of making and breaking bonds.

Both required to be correct for Excellence

Answer 2c (iii):



Answer 2c (iv): When butane undergoes combustion, heat is released, so it is an exothermic reaction.

Bond-making is an exothermic process / releases energy and bond-breaking is endothermic / requires energy. For the overall reaction in the combustion of butane to release energy, more energy is given out as bonds are made (when the products, CO_2 and H_2O are formed) than the energy being used to break the bonds (in the reactants, C_4H_{10} and O_2).

NCEA 2016 Enthalpy

Achieved Question

Question 1a Instant cold packs are useful for treating sports injuries on the field. They contain salts such as ammonium nitrate, NH_4NO_3. When the packs are activated, the salt dissolves in water, causing the temperature to decrease.

- Identify the term that best describes this reaction
- Give a reason for your choice

Heat absorbed is always endothermic

Answer 1a : Endothermic
The temperature decreased OR heat / energy has been absorbed.

Question 1b: The equation for hydrating anhydrous copper sulfate is as follows:

$CuSO_{4(s)} + 5H_2O_{(l)} \rightarrow CuSO_4.5H_2O_{(s)}$ $\Delta_r H^\circ = -78.2$ kJ mol^{-1}

- Identify the term that best describes this reaction
- Give a reason for your choice

Answer 1b: Exothermic.
The enthalpy of the reaction is negative / energy has been released.

NCEA 2016 Enthalpy

Excellence Question

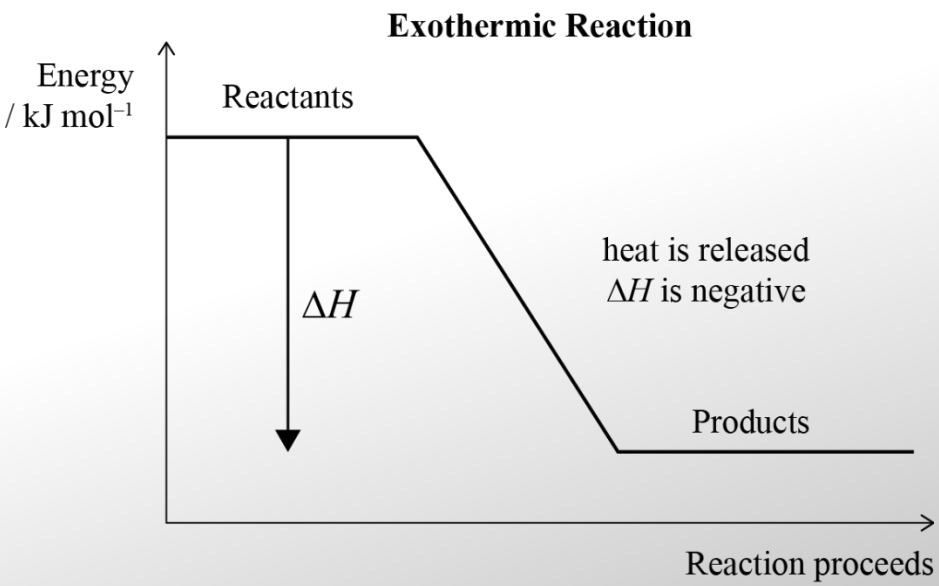
Question 1c (i): Pentane, C_5H_{12}, is a liquid at room temperature. It evaporates at 36.1°C in an endothermic process.
(i) Explain why the evaporation of pentane is an endothermic process.

Answer 1c(i) : Energy is required to change pentane from a liquid to a gas. The energy / heat is used to break weak intermolecular forces / bonds / attraction between pentane molecules.

Solid →liquid →gas is always endothermic

Question 1c(ii) : Draw, including labels, the energy diagram for the combustion of pentane, $C_5H_{12(l)}$.
Pentane combustion: $C_5H_{12(l)} + 8O_{2(g)} \rightarrow 5CO_{2(g)} + 6H_2O_{(l)}$
$\Delta_r H^\circ = -3509$ kJ mol^{-1}
Include in your diagram the reactants, products, and change in enthalpy.

Answer 1c(ii)



NCEA 2017 Enthalpy

Merit Question

Question 1a: When solid calcium chloride, $CaCl_{2(s)}$, reacts with water, the temperature increases.
Which term that best describes this reaction.

Temperature increase is always exothermic

Exothermic
The temperature increased / energy or heat has been released into the surroundings /
energy is lost from the substance ($CaCl_2$)

Question 1b (i): When a person sweats, water is lost from the body by evaporation. This is an endothermic process. This evaporation speeds up when a person exercises.
(i) Explain why the evaporation of water in sweat from the body is endothermic, and why exercise increases this evaporation.

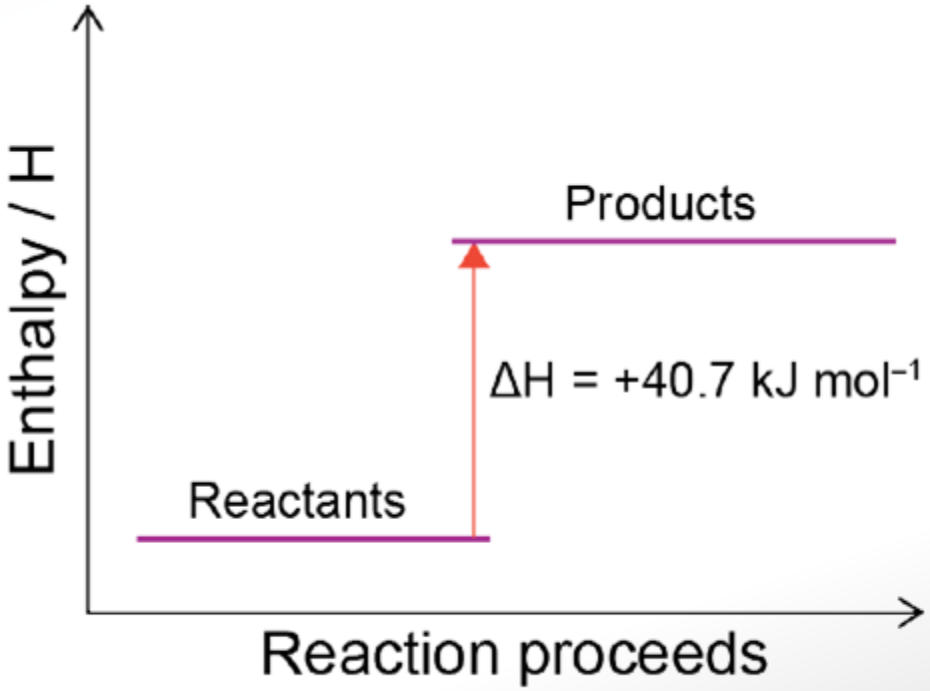
The water in sweat is changing state from liquid to gas. It needs to absorb energy to break the forces / bonds between liquid water molecules. It absorbs this from the heat of the body. The temperature of the body increases when exercising, so more water can be evaporated.

NCEA 2017 Enthalpy

Excellence Question with b(i)

Question 1b (ii): Draw a labelled enthalpy diagram for the evaporation of water, $H_2O_{(\ell)}$.

$H_2O_{(\ell)} \rightarrow H_2O_{(g)}$ $\Delta_r H° = 40.7$ kJ mol^{-1}



Can show activation energy but not required.

NCEA 2018 Enthalpy

Achieved Question

Question 1a. The equation for the dissolving of ammonium chloride, NH_4Cl, in water is shown below.

$NH_4Cl_{(s)} \rightarrow NH_4^+{}_{(aq)} + Cl^-{}_{(aq)}$ $\Delta_r H^o = +17.8$ kJ mol^{-1}

Circle the term that best describes this reaction:

Endothermic **exothermic**

Give a reason for your choice.

Endothermic because the enthalpy change is positive.

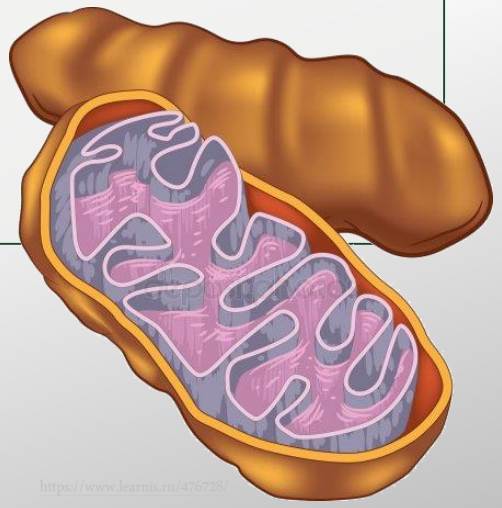
Question 1b (i) Respiration is the process by which energy is released from glucose.

$C_6H_{12}O_{6(s)} + 6O_{2(g)} \rightarrow 6CO_{2(g)}) + 6H_2O_{(\ell)}$

Circle the term that best describes this reaction:

endothermic **exothermic**

Give a reason for your choice.



Exothermic because energy is released.

https://www.learnis.ru/476728/

NCEA 2018 Enthalpy

Merit Question

Question 1b (ii) . Water formed in the respiration reaction evaporates.

$H_2O_{(\ell)} \rightarrow H_2O_{(g)}$

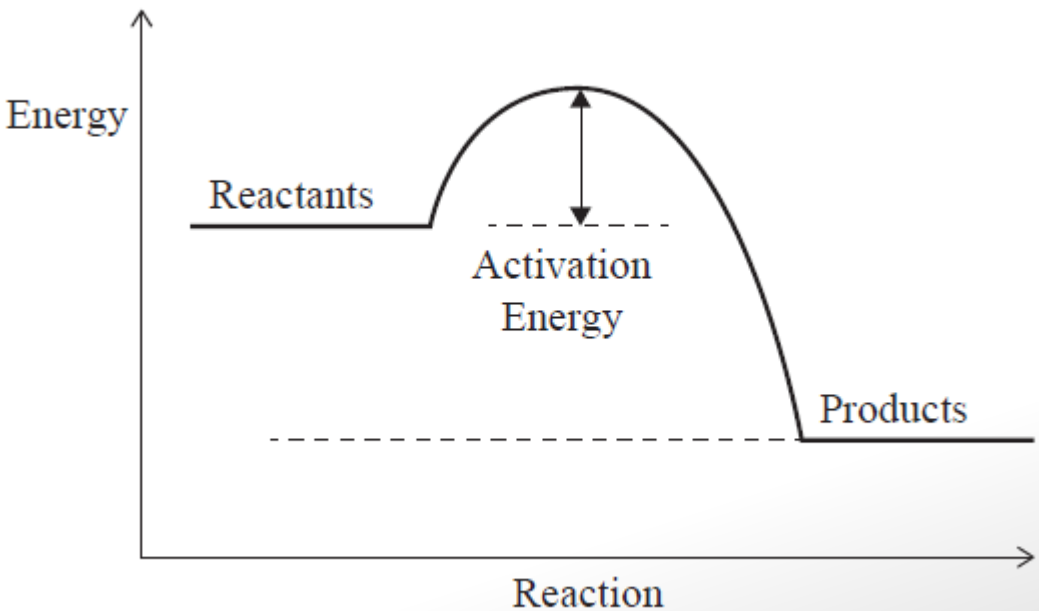
Explain whether this process is endothermic or exothermic

The evaporation of water is endothermic because energy is absorbed to break the attractive forces between water molecules.

NCEA 2018 Enthalpy

Merit Question

Question 1c. (i) Butane is used to fuel a camping stove. Butane burns readily in oxygen.
The following is an energy profile diagram for the combustion of butane.
Explain how the diagram shows that the enthalpy change for this reaction is negative.



This is an exothermic reaction; the total energy of the products is less than the total energy of the reactants. Therefore, as the change in enthalpy is the difference in energy between products and reactants, the change is negative and the difference in energy is released as heat to the surroundings

NCEA 2019 Enthalpy

Excellence Question

Question 1d. Ice, $H_2O_{(s)}$, is often placed into drinks. As the ice melts, the drink cools.
$H_2O_{(s)} \rightarrow H_2O_{(l)}$ $\Delta_r H = +\ 6.01\ \text{kJ mol}^{-1}$
Use your knowledge of enthalpy changes associated with changes of state to elaborate on the reason why the drink cools.

The melting of ice is endothermic, as (intermolecular) bonds are being broken as water changes from solid to liquid. This requires energy to be absorbed from the surroundings/the drink. This causes the temperature of the drink to decrease.

NCEA 2013 Thermochemical calculations

Excellence Question

Question 3b(ii) : Females who are moderately active need 9 800 kJ of energy per day. Calculate the number of moles of glucose that would provide this daily energy requirement.

$C_6H_{12}O_{6(s)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(\ell)}$ $\Delta_r H° = -2\,820$ kJ mol^{-1}

Answer 3b(ii):

9800 kJ / 2820 kJ mol–1 = 3.48 mol

Question 3c(ii) : The equation below shows the combustion of butane.

$C_4H_{10(g)} + 13/2\ O_{2(g)} \rightarrow 4CO_{2(g)} + 5H_2O_{(g)}$ $M(C_4H_{10}) = 58.1$ g mol^{-1}.

When 100 g of butane undergoes combustion, 4 960 kJ of energy is released.

Calculate the enthalpy change when 1 mole of butane undergoes combustion.

Answer 3c(ii):

$n(C_4H_{10})$ = 100 g / 58.1 g mol^{-1}

= 1.7212 mol

–4960 kJ / 1.7212 mol = –2882 kJ mol^{-1}

Calculating the amount of energy per mole

An equation and n=m/M are required for this type of thermochemical calculation

NCEA 2013 Thermochemical calculations

Excellence Question

Question 3d: The iron oxides Fe_3O_4 and Fe_2O_3 react with aluminium as shown below.

$3Fe_3O_{4(s)} + 8Al_{(s)} \rightarrow 4Al_2O_{3(s)} + 9Fe_{(s)}$ $\Delta_r H° = -3\ 348$ kJ mol^{-1}

$Fe_2O_{3(s)} + 2Al_{(s)} \rightarrow Al_2O_{3(s)} + 2Fe_{(s)}$ $\Delta_r H° = -851$ kJ mol^{-1}

Justify which iron oxide, Fe_3O_4 or Fe_2O_3, will produce more heat energy when 2.00 kg of iron is formed during the reaction with aluminium.

Your answer should include calculations of the heat energy produced for the given mass of iron formed.

M(Fe) = 55.9 g mol^{-1}.

n(Fe) = 2000 g / 55.9 g mol–1 = 35.78 mol

Fe_3O_4:

3348 kJ / 9 = 372 kJ mol–1

372 kJ mol–1 × 35.78 mol = 13 310.16 kJ

= (–)1.33 ×10^4 kJ

Fe_2O_3:

851 kJ / 2 = 425.5 kJ mol–1

425.5 kJ mol–1 × 35.78 mol = 15 224.4 kJ

= (–)1.52 × 10^4 kJ

Complete each calculation one after the other

Don't forget to make a comparison statement

Therefore Fe_2O_3 produces more heat energy when 2 kg iron is formed.

NCEA 2014 Thermochemical calculations

Excellence Question

Question 3c: Methanol and ethanol can both be used as fuels. Their combustion reactions can be represented by the following equations:

Methanol combustion: $2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$ $\Delta_r H^o = -1450$ kJ mol^{-1}

Ethanol combustion: $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$ $\Delta_r H^o = -1370$ kJ mol^{-1}

Justify which fuel, methanol or ethanol, will produce more heat energy when 345 g of each fuel is combusted in excess oxygen.

$M(CH_3OH) = 32.0$ g mol^{-1}

$M(C_2H_5OH) = 46.0$ g mol^{-1}

Answer 3c :

$n(CH_3OH) = m / M = 345 / 32 = 10.78$ mol

$n(C_2H_5OH) = m / M = 345 / 46 = 7.50$ mol

Complete each calculation one after the other

2 mol CH_3OH release 1 450 kJ of energy

1 mol CH_3OH releases 725 kJ of energy

10.78 mol CH_3OH releases 725 kJ x 10.78mol

= 7 816 kJ of energy

Don't forget to make a comparison statement

1 mol C_2H_5OH releases 1 370 kJ of energy

7.5 mol C_2H_5OH releases 1 370 kJ x 7.50mol = 10 275 kJ of energy

Therefore C_2H_5OH releases more energy when 345 g of fuel are combusted.

NCEA 2015 Thermochemical calculations

Excellence Question

Question 2b(ii) : Calculate how much energy is absorbed or released in the photosynthesis reaction if 19.8 g of carbon dioxide gas, $CO_{2(g)}$, reacts completely with excess water, $H_2O_{(l)}$, to form glucose, $C_6H_{12}O_{6(aq)}$, and oxygen gas, $O_{2(g)}$. Show your working and include appropriate units in your answer.

$M(CO_2) = 44.0$ g mol^{-1}

$6CO_{2(g)} + 6H_2O_{(l)} \rightarrow C_6H_{12}O_{6(aq)} + 6O_{2(g)}$ $\Delta_r H° = +2803$ kJ mol^{-1}

An equation and n=m/M are required for this type of thermochemical calculation

Answer 2b(ii):

$n(CO_2) = m/M = 19.8/44.0 = 0.450$mol

Convert mass into mols

Since 6 moles of CO_2 reacting requires 2803 kJ of energy then 1 mole of CO_2 reacting requires 2803/6 = 467.2 kJ of energy and 0.450 moles of CO_2 requires 467.2 x 0.450 = 210 kJ of energy absorbed.

Units are in kJ and the + sign indicates energy is absorbed

NCEA 2015 Thermochemical calculations - (Part ONE)

Excellence Question

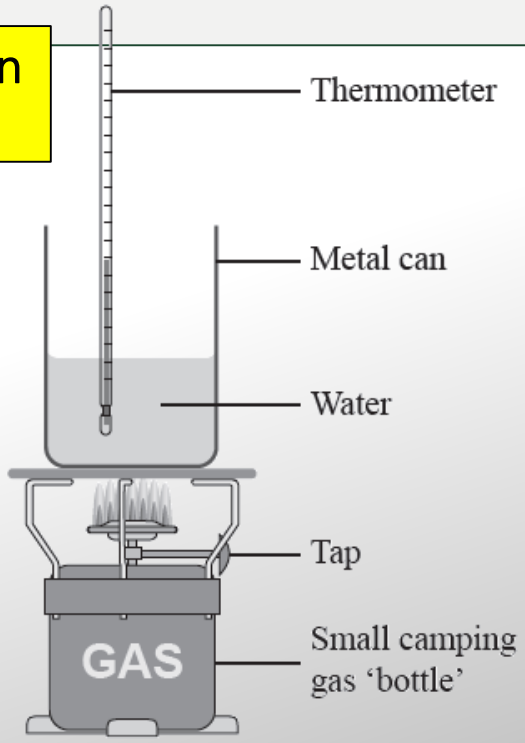
Question 2c: A small camp stove containing butane gas, $C_4H_{10(g)}$, is used to heat some water, as shown in the diagram below. A student measures the temperature change in the water and calculates that when 3.65 g of butane is combusted, 106 kJ of heat is released.

The reaction for the combustion of butane is shown in the equation below.

$2C_4H_{10(g)} + 13O_{2(g)} \rightarrow 8CO_{2(g)} + 10H_2O_{(l)}$

(i) Calculate the enthalpy change ($\Delta r\ H$) for this reaction, based on the above measurements. $M(C_4H_{10}) = 58.0$ g mol^{-1}

Values are all given to 3 sgf



Answer 2c:

$n(C_4H_{10}) = m/M \quad = 3.65/58.0 \quad = 0.0629$mol

If 0.0629 moles of C_4H_{10} releases 106 kJ of energy

Then 1 mole of C_4H_{10} releases 106/0.0629 = 1685 kJ of energy

And 2 moles of C_4H_{10} releases 1685 x 2 = 3370 kJ of energy (3368) ($\Delta_r H = -3370$ kJ mol^{-1}

Must show sign

NCEA 2015 Thermochemical calculations - (part TWO)

Excellence Question

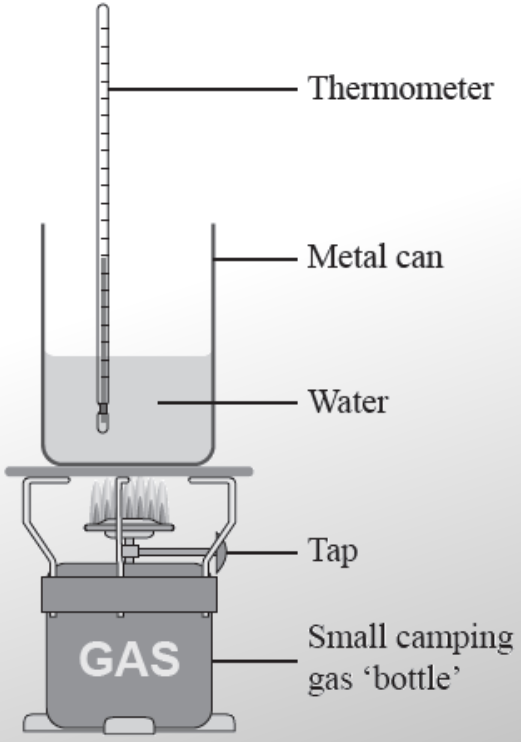
Question 2c: (ii) The accepted enthalpy change for the combustion reaction of butane gas, $C_4H_{10(g)}$, is $\Delta r\ H = -5754$ kJ mol^{-1}.
Explain why the result you calculated in part (c)(i) is different to the accepted value.
In your answer, you should include at least TWO reasons.

TWO errors required for Excellence

Answer 2c: The results from this experiment are less than the accepted results, due to errors in the experimental design.
The errors could include:

1. Some energy is used to heat the metal can and the air surrounding the experiment / the experiment was not conducted in a closed system
2. Incomplete combustion of butane.
3. Some butane may have escaped before being ignited.
4. The butane in the gas canister was impure.
5. Some water evaporated
6. Some energy was converted to light and sound
7. Not carried out under standard conditions

Therefore, not all of the energy released by the combustion of butane was transferred to heating the water.



NCEA 2016 Thermochemical calculations

Excellence Question

Question 1c(iii): Hexane, C_6H_{14}, like pentane, will combust (burn) in sufficient oxygen to produce carbon dioxide gas and water. Pentane combustion: $\Delta_r H^\circ = -3509$ kJ mol^{-1}
Hexane combustion: $2C_6H_{14(l)} + 19O_{2(g)} \rightarrow 12CO_{2(g)} + 14H_2O_{(l)}$ $\Delta_r H^\circ = -8316$ kJ mol^{-1}
Justify which alkane – pentane or hexane – will produce more heat energy when 125 g of each fuel is combusted in sufficient oxygen.
$M(C_5H_{12}) = 72.0$ g mol^{-1} $M(C_6H_{14}) = 86.0$ g mol^{-1}

An equation and n=m/M are required for this type of thermochemical calculation

Answer 1c(iii):

n (pentane) = 125 g / 72.0 g mol^{-1} = 1.74 mol
n (hexane) = 125 g / 86.0 g mol^{-1} = 1.45 mol
If 1 mole of pentane releases 3509 kJ energy,
then 1.74 mol of pentane:
1.74 × 3509 = 6106 kJ energy released.

Convert mass into mols

If 2 moles of hexane release 8316 kJ energy,
then 1 mole of hexane releases 4158 kJ energy.
So 1.45 mol of hexane 1.45 × 4158 = 6029 kJ energy releases.

So pentane releases more energy (77.0 kJ) than hexane, per 125 g of fuel.

Make sure both fuels are compared for Excellence

NCEA 2017 Thermochemical calculations

Excellence Question

Question 1c: Thermite reactions occur when a metal oxide reacts with a metal powder. The equations for two thermite reactions are given below:

Reaction 1: $Fe_2O_{3(s)} + 2Al_{(s)} \rightarrow 2Fe_{(s)} + Al_2O_{3(s)}$ $\Delta_rH° = -852$ kJ mol^{-1}

Reaction 2: $3CuO_{(s)} + 2Al_{(s)} \rightarrow 3Cu_{(s)} + Al_2O_{3(s)}$) $\Delta_rH° = -1520$ kJ mol^{-1}

Use calculations to determine which metal oxide, iron(III) oxide, $Fe_2O_{3(s)}$, or copper(II) oxide, $CuO_{(s)}$, will produce more heat energy when 50.0 g of each metal oxide is reacted with aluminium powder, $Al_{(s)}$.

$M(Fe_2O_3) = 160$ g mol^{-1} $M(CuO) = 79.6$ g mol^{-1}

An equation and n=m/M are required for this type of thermochemical calculation

$n(Fe_2O_3) = \frac{50.0 \text{ g}}{160 \text{ g mol}^{-1}} = 0.313$mol

$n(CuO) = \frac{50.0 \text{ g}}{79.6 \text{ g mol}^{-1}} = 0.628$ mol

Convert mass into mols

Reaction 1: If 1 mole of Fe_2O_3 releases 852 kJ energy

0.313 mol × 852 kJ mol^{-1} = 266 kJ energy released

Reaction 2: If 3 mole of CuO releases 1520 kJ energy

Then 1 mole of CuO releases 507 kJ energy

0.628 mol × 507 kJ mol–1 = 318 kJ energy released

So 50.0 g CuO releases more energy than 50.0 g Fe_2O_3

OR

CuO releases more energy (52 kJ) than Fe_2O_3

(**Reaction 2** releases more energy.)

Make sure both substances are compared for Excellence

NCEA 2018 Thermochemical Calculations

Excellence Question

Question 1c. (ii) The following is the equation for the combustion of butane gas in oxygen.

$2C_4H_{10(g)} + 13O_{2(g)} \rightarrow 8CO_{2(g)} + 10H_2O_{(g)}$ $\Delta_r H^o = -5760$ kJ mol^{-1}

The fuel cylinder for the stove contains 450 g of butane gas.

Calculate the energy released when this mass of butane gas is burned completely in oxygen.

Show your working and include appropriate units in your answer.

$M(C_4H_{10}) = 58.0$ g mol^{-1}

If 2 moles of butane produce 5760 kJ then 1 mole produces 2880 kJ.

n(butane) = 450 / 58.0

= 7.76 moles

q = 7.76 × 2880 = <u>22 300 kJ released</u>

alternative:

n(butane) = 450 / 58.0

= 7.76 moles

so n(reaction) = n(butane)/2 = 3.88 mol

So q = 5760 x 3.88 = <u>2.23 x 10^4 kJ released</u>

NCEA 2018 Thermochemical Calculations

Excellence Question

Question 2d. Methanol, $CH_3OH_{(\ell)}$, is made industrially by reacting carbon monoxide, $CO_{(g)}$, and hydrogen, $H_{2(g)}$.

$CO_{(g)} + 2H_{2(g)} \rightarrow CH_3OH_{(\ell)}$ $\Delta_r H^o = -91.0$ kJ mol^{-1}

Calculate the volume of methanol made when 4428 kJ of energy is released.

The mass of 1.00 L of methanol is 0.790 kg.

$M(CH_3OH) = 32.0$ g mol^{-1}

https://www.safeproof.org/greece-liquor-enforcement-methanol-alcohol-poisoning/

n(methanol) = 4428 / 91
= 48.7 moles

mass (methanol) = 48.66 × 32 = 1557 g

volume (methanol) = 1.56 / 0.790
= <u>1.97 L</u>

NCEA 2019 Thermochemical Calculations

Excellence Question

Question 3b. When magnesium, $Mg_{(s)}$, is burned, it produces a white powder according to the equation below.

$2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$ $\Delta_r H = -1203$ kJ mol^{-1}

(i) Calculate the mass of oxygen required to produce 1804.5 kJ of energy.

M(O) = 16.0 g mol^{-1}

$$n(O_2(g)) = \frac{1804.5}{1203} = 1.5 \text{ moles}$$

$$m = n \times M = 1.5 \times 32 = 48.0 \text{ g}$$

(ii) Calculate the energy change when 100 g of $MgO_{(s)}$ is produced.

M(MgO) = 40.3 g mol^{-1}

$$n = \frac{m}{M} = \frac{100}{40.3} = 2.48$$

$$\text{Energy} = \Delta_r H \times n = \frac{-1203}{2} \times 2.48 = -1492.5 \text{ kJ} / -1493 \text{ kJ}$$

-1490 kJ (3 sf)

(either positive or negative values accepted)

NCEA 2019 Thermochemical Calculations

Excellence Question

Question 3c. A common industrial process is the extraction of metals from their ores. Aluminium is found naturally in aluminium oxide, and the oxygen is removed to produce the metal. Information is given below of the enthalpy change when aluminium, $Al_{(s)}$, is extracted.

$2Al_2O_{3(s)} \rightarrow 4Al_{(s)} + 3O_{2(g)}$ $\Delta_r H = 3350$ kJ mol^{-1}

A production plant produces 65.0 kg (65 000 g) of aluminium per minute. Calculate how much energy is required per hour of production of aluminium. Round your answer to 3 significant figures. $M(Al) = 27.0$ g mol^{-1}

$$65\,000 \times 60 = 3\,900\,000 \text{ g}$$

$$n(\text{Al}) = \frac{3\,900\,000}{27} = 144\,444 \text{ moles}$$

$$\Delta_r H = \frac{144\,444}{4} \times 3350$$

$$= 121\,000\,000 \text{ kJ} = 1.21 \times 10^8 \text{ kJ (rounded to 3sf)}$$

$$\text{OR } \frac{65000}{27} = 2407 \text{ moles}$$

$$\Delta_r H = \frac{2407}{4} \times 3350 = 2\,015\,862 \text{ kJ} \times 60$$

$$= 121\,000\,000 \text{ kJ} = 1.21 \times 10^8 \text{ kJ (rounded to 3sf)}$$

Draw Lewis structures if not given

NCEA 2013 Bond Enthalpy

Excellence Question

Question 2c: Chlorine reacts with methane to form chloromethane and hydrogen chloride, as shown in the equation below.

$CH_{4(g)} + Cl_{2(g)} \rightarrow CH_3Cl_{(g)} + HCl_{(g)}$

Use the following bond enthalpies to calculate Δr *H*° for this reaction.

$\Delta_r H^o = \Sigma$Bond energies(bonds broken) – ΣBond energies(bonds formed)

Bond energies always given – use units on chart to remind you

Bonds broken		Bonds formed	
C-H x 4	1656	C–Cl	324
Cl–Cl	242	C–H	3 × 1242
	1898	H-Cl	431
			1997

= 1898 – 1997 = –99 kJ mol^{-1}

Alternative calculation that includes the breaking and reforming of only the bonds involved in the reaction

(656 – 755 = 99kJ mol^{-1})

Bond	Bond enthalpy /kJ mol^{-1}
H–Cl	431
C–H	414
C–Cl	324
Cl–Cl	242

NCEA 2014 Bond Enthalpy

Excellence Question

Question 1d: Hydrogen gas, $H_{2(g)}$, reacts with oxygen gas, $O_{2(g)}$, as shown by the following equation

$$H_{2(g)} + \frac{1}{2} O_{2(g)} \rightarrow H_2O_{(g)} \quad \Delta_r H^o = -242 \text{ kJ mol}^{-1}$$

Given the average bond enthalpies in the table below, calculate the average bond enthalpy of the **O – H** bond in H_2O.

$\Delta_r H^o = \Sigma$Bond energies(bonds broken) – ΣBond energies(bonds formed)

Bond energies always given – use units on chart to remind you

Bond	Average bond enthalpy / kJ mol^{-1}
H–H	436
O=O	498

Bonds broken
H–H = 436
½ × O=O = ½ × 498
Total = 685 kJ mol^{-1}

Bonds formed
2 × O–H
Total = ?

–242 kJ mol^{-1} = 685kJ - ?
? = 685 – (– 242)
= 927 kJ mol^{-1}

Swap total and ?

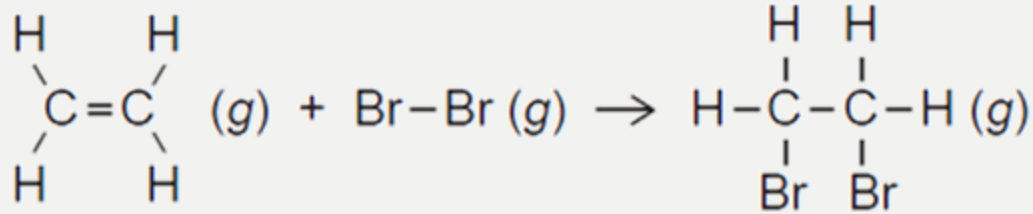
2 × O–H = 927 kJ mol^{-1}
but ONE **O–H** = 464 (463.5) kJ mol^{-1}

NCEA 2015 Bond Enthalpy

Excellence Question

Question 1d: Ethene gas, $C_2H_{4\,(g)}$, reacts with bromine gas, $Br_{2(g)}$, as shown in the equation below.
Calculate the enthalpy change, $\Delta_r H°$, for the reaction between ethane and bromine gases, given the average bond enthalpies in the table below. Show your working and include appropriate units in your answers.

Draw Lewis structures if not given



$\Delta_r H^o$ = ΣBond energies(bonds broken) – ΣBond energies(bonds formed)

Bond energies always given – use units on chart to remind you

Bond	Average bond enthalpy/kJ mol^{-1}
Br–Br	193
C–C	346
C=C	614
C–Br	285
C–H	414

Bonds broken		Bonds formed	
C=C	614	C–C	346
Br–Br	193	C–Br	2 × 285
	807		916

= 807 – 916 = –109 kJ mol^{-1}

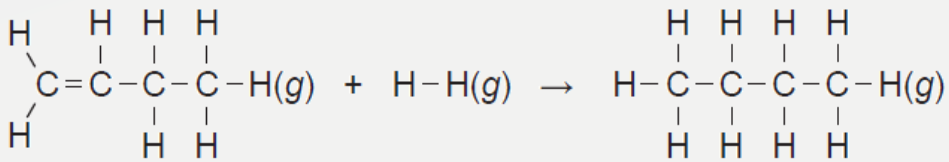
Alternative calculation that includes the breaking and reforming of four C-H bonds
(or 2463 – 2572)

Draw Lewis structures if not given

NCEA 2016 Bond Enthalpy

Excellence Question

Question 3c: Calculate the enthalpy change, $\Delta_r H°$, for the reaction of but-1-ene gas, $C_4H_{8(g)}$, with hydrogen gas, $H_{2(g)}$, to form butane gas, $C_4H_{10(g)}$.
Use the average bond enthalpies given in the table below.



Bond energies always given – use units on chart to remind you

Bond	Average bond enthalpy / kJ mol^{-1}
C=C	614
C–C	346
C–H	414
H–H	436

Bond breaking

C=C 614
C–C × 2 692
C–H × 8 3312
H–H 436
5054 kJ mol^{-1}

Bond making

C–C × 3 1038
C–H × 10 4140
5178 kJ mol^{-1}

$\Delta_r H°$ = Bond breaking – bond making
$\Delta_r H°$ = 5054 kJ mol^{-1} – 5178 kJ mol^{-1}
$\Delta_r H°$ = –124 kJ mol^{-1}

Alternative calculation that includes the breaking and reforming of only the bonds involved in the reaction

$\Delta_r H°$ = 1050 – 1174 = –124 kJ mol^{-1}

NCEA 2017 Bond Enthalpy

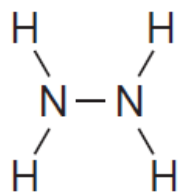
Excellence Question

Question 2c: Hydrazine, N_2H_4, is used as rocket fuel.
Use calculations to determine which of **Reaction 1** or **Reaction 2** releases more energy.

Reaction 1: $N_2H_{4(g)} + O_{2(g)} \rightarrow N_{2(g)} + 2H_2O_{(g)}$

Reaction 2: $N_2H_{4(g)} + 2F_{2(g)} \rightarrow N_{2(g)} + 4HF_{(g)}$

The structure of each chemical species is shown in the box below. Show your working and include appropriate units in your answer.



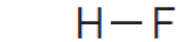
hydrazine

oxygen

fluorine

nitrogen

water



hydrogen fluoride

Use the average bond enthalpies given in the table below.

Bond	Average Bond enthalpy /kJ mol^{-1}	Bond	Average Bond enthalpy /kJ mol^{-1}
H–H	436	N–N	158
H–F	567	F–F	159
N–H	391	O=O	498
O–H	463	N≡N	945

NCEA 2017 Bond Enthalpy

Excellence Question

Question 2c: Hydrazine, N_2H_4, is used as rocket fuel.
Use calculations to determine which of **Reaction 1** or **Reaction 2** releases more energy.

Reaction 1
Hydrazine and oxygen

Bond breaking		Bond making	
N–N	158	N≡N	945
N–H × 4	1564	O–H × 4	1852
O=O	498		2797
	2220		

Bond breaking – bond making
2220 – 2797 = –577 kJ mol^{-1}

Reaction 2
Hydrazine and Fluorine

N–N	158	N≡N	945
N–H × 4	1564	H–F × 4	2268
F–F × 2	318		3213
	2040		

Bond breaking – bond making
2040 – 3213 = –1173 kJ mol^{-1} (or -1170 kJ mol^{-1})
Reaction 2 releases more energy than **Reaction 1** (by 596 kJ mol^{-1}).

NCEA 2018 Bond Enthalpy

Excellence Question

Question 1d. Nitrogen gas, $N_{2(g)}$, reacts with hydrogen gas, $H_{2(g)}$, to produce ammonia gas, $NH_{3(g)}$, as shown by the following equation:

$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)} \quad \Delta_r H^o = -92.0 \text{ kJ mol}^{-1}$

Calculate the average bond enthalpy of the **N–H** bond in 3, using the average bond enthalpies in the table below.

Bond	Average bond enthalpy kJ mol^{-1}
N≡N	945
H–H	436

$\Delta H = \Sigma E(\text{Bonds broken}) - \Sigma E(\text{Bonds made}) = -92.0 \text{ kJ mol}^{-1}$

$E(N{\equiv}N) + 3E(H{-}H) - 6E(N{-}H) = -92.0 \text{ kJ mol}^{-1}$

$6E(N{-}H) = 2253 - (-92.0) = 2345 \text{ kJ mol}^{-1}$

Therefore $E(N{-}H) = 2345 / 6$

$= \underline{391 \text{ kJ mol}^{-1}}$

https://www.newsroom.co.nz/category/nation/2018/03/30/4-factory-workers-affected-by-ammonia-gas-leak/

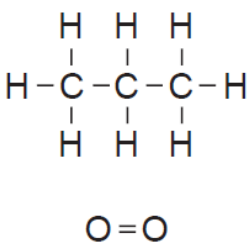
NCEA 2019 Bond Enthalpy

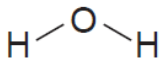
Excellence Question

Question 2c. When propane, $C_3H_{8(g)}$, is burned, it reacts with oxygen, $O_{2(g)}$, in the air to form water, $H_2O_{(g)}$, and carbon dioxide, $CO_{2(g)}$.

$C_3H_{8(g)} + 5O_{2(g)} \rightarrow 4H_2O_{(g)} + 3CO_{2(g)}$ $\Delta_r H = -2056$ kJ mol^{-1}

Calculate the average bond enthalpy of the C = O bond using the data below.





O=O

Bond	Average bond enthalpy/kJ mol^{-1}
C – C	348
C – H	413
O = O	495
O – H	463

Bond breaking

2 x C – C = 348 x 2 = 696

8 x C – H = 413 x 8 = 3304

5 x O = O = 495 x 5 = 2475

Total = **6475**

Bond making

8 x O – H = 463 x 8 = 3704

6 x C = O = 6*x*

$\Delta_r H$ = ΣBond energies (bonds broken) – ΣBond energies (bonds formed)

6475 – 3704 – 6*x* = –2056 kJ mol^{-1}

6*x* = + 2056 + 6475 – 3704 = 4827 *x* = 805 kJ mol^{-1}